TEMPORARY MANUAL ~~TP 524~~

FREQUENCY COUNTER NO. 14-20 FM

NORTHEASTERN ENGINEERING, INC.
MANCHESTER, NEW HAMPSHIRE

TEMPORARY

INSTRUCTION MANUAL

FREQUENCY COUNTER

NO. 14-20 FM

THIS IS A TEMPORARY MANUAL AND WILL BE REPLACED BY THE PERMANENT EDITION CURRENTLY IN PRODUCTION WHEN IT BECOMES AVAILABLE.

NORTHEASTERN ENGINEERING, INC.
MANCHESTER, NEW HAMPSHIRE

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FREQUENCY COUNTER
NO. 14-20FM

CHAPTER I

GENERAL INFORMATION

The Frequency Counter No. 14-20 FM is an extremely versatile precision type direct reading instrument capable of measuring frequencies, time intervals, periods, time and frequency ratios, frequency drift and similar quantities and of counting and totalizing discreet electrical impulses such as are found in pulse and nuclear work whether of regular or random occurence. It may also be used as a secondary frequency with outputs at 10 cps, 1 Kc, 100 Kc, and 10 Mc. It has two outstanding characteristics not found in units of similar purpose (1) an extreme range of coverage (frequencies from 10 cps to a maximum of 100 Mc with Frequency Converter 14-21 C unit and time intervals from 1 microsecond to 100 days) and (2) direct display of the answer in its final form with automatic placement of decimal point without the necessity of further calculation or interpolation. This second feature, together with simplicity in the operating controls make it an ideal instrument for use by non-technical personnel.

The high precision internal oscillator, controlled by a crystal enclosed in a constant temperature oven, furnishes the frequency standard and provides a self-checking feature for the counter without the necessity of providing expensive extra equipment for this purpose.

The basic feature of the unit is a precision time base generator, operating from the crystal-controlled 100 Kc precision oscillator, which opens and closes a gating circuit allowing the signal under measurement to actuate a counting circuit for a known interval of time, thus giving a direct reading of cycles per unit time or frequency. The counting circuit is arranged to read directly in kilocycles.

Period or time intervals are measured by reversing the roles of the time base generator and the signal under measurement. In this case, one cycle of the signal opens and a succeeding cycle closes the gating circuit, allowing the known frequency of the time base generator to be displayed. Frequencies of the time base generator are selected to give displayed counts in direct units of time, i.e., seconds, milliseconds or microseconds.

TECHNICAL SPECIFICATIONS.

Frequency Counter No. 14-20 FM

Range:	10 cps to 10 Mc direct reading
Accuracy:	±1 count ±0.0002%
Input voltage:	1 volt rms minimum
Input impedance:	1 megohm with 40 mmf shunt
Power:	115v, 50-1000 cps, 575 watts
Dimensions:	19-¼ in. by 19 in. by 18-¾ in.
Weight:	110 lbs.

Accessories furnished:

Transit case (large): 22-½ by 23-¼ by 23-¼ inches
Transit case (small): 8-¼ by 12 by 8 inches
Power cable: one
Input cable: one
Test cable: three
Adapters: fourteen

Frequency Converter 14-21C (used with basic unit 14-20 FM)

Function: extends the range of the basic unit to measure frequencies up to 100 Mc and also provides additional amplification in the 10 cps to 10 Mc range to increase the sensitivity of the unit to 0.02 volt.

Range: used as amplifier, 10 cps to 10 Mc; as converter 10 Mc to 100 Mc.

Accuracy: ±1 count ±0.0002%
Input voltage: 0.02 volt rms minimum (converter), 0.2 volt rms (amplifier)
Input impedance: 1 megohm with 40 mmf, 10 cps to 10 Mc; 50 ohms 10 Mc to 100 Mc
Dimensions: 6-3/8 in. by 10 in. by 6-1/4 in.
Weight: 5 lbs

Time Interval Unit 14-241 (used with basic unit 14-20 FM)

Function: enables the basic unit to be used for measuring elapsed intervals of time from 1 microsecond up to 10,000,000 seconds (approx. 100 days). It has one start and one stop channel which can be used independently or in common and it will trigger from either positive-going or negative-going input voltages. Counters can be set to read results in seconds, milliseconds, or microseconds with automatic placement of the decimal point.

Range: 1 microsecond to 10,000,000 seconds
Accuracy: ±1 microsecond ±0.0002%
Input voltage: adjustable from −200 to + 200 volts, both channels
Input impedance: 1 megohm with 40 mmf shunt approx.
Trigger Amplitude: 2 volt peak minimum, direct coupled
Dimensions: 6-3/8 by 10 by 6-¼ inches
Weight: 4 lbs

TUBE COMPLEMENT

Frequency Counter No. 14-20 FM

Section	Symbol	Type	Function
Gate Section	V201	12AT7WA	Input Cathode Follower - Amplifier
	V202	5725/6AS6W	Signal Gate
	V203	6AH6	Gate Control Amplifier
	V204	5963	Display Time Control
	V205	5727/2D21W	Display Time Thyratron
	V206	6AH6	Gate Binary
	V207	6AH6	Gate Binary
	V208	5963	Cathode Follower - Blocking Oscillator
	V209	5727/2D21W	Reset Thyratron
Counter Section	V210	6AH6	First Binary, Units
	V211	6AH6	First Binary, Units
	V212	6CB6	Second Binary, Units
	V213	6CB6	Second Binary, Units
	V214	5725/6AS6W	Feedback Gate
	V215	6CB6	Third Binary, Units
	V216	6CB6	Third Binary, Units
	V217	6AH6	Fourth Binary, Units
	V218	6CB6	Fourth Binary, Units
	V219	5963	First Binary, Tens
	V220	5963	Second Binary, Tens
	V221	5963	Third Binary, Tens

Section	Symbol	Type	Function
Time Base Section	V222	5963	Fourth Binary, Tens
	V223	5963	Tens Counter Output Wave-shaper
	V234	6AU6WA	100 Kc Oscillator
	V235	5726/6AL5W	Clamp - Coupling Diode.
	V236	5963	100 Kc Blocking Oscillator - Buffer
	V237	6AU6WA	Multipliers
	V238	6AU6WA	Multipliers
	V239	6CB6	Multiplier
	V240	6AH6	Amplifier, 10 Mc
	V241 to V247	5725/6AS6W	First to Fifth Phantastrons
	V248	5963	Cathode Follower
Power Supply Section	V249	5R4WGY	Rectifiers
	V250	5R4WGY	Rectifier
	V251	5R4WGY	Rectifier
	V252	6AU6WA	Control
	V253	6080WA	Regulator
	V254	6080WA	Regulator
	V255	5687	Regulator
	V256	12AT7WA	Control
	V257	5Y3WGTA	Rectifier
	V258	6005/6AQ5W	Regulator
	V260	6AU6WA	Control
	V261	OB2WA	Reference
Amplitude Discriminator	V702	5844	Schmidt Trigger
	V701	12AT7WA	Stabilized Amplifier
Decade Divider	V801	5963	First Binary
	V802	5963	Second Binary
	V803	5963	Third Binary
	V804	5963	Fourth Binary
Trigger Unit	V1101	5963	Stabilized Amplifier
	V1102	5654/6AK5W	Schmidt Trigger
	V1103	5654/6AK5W	Schmidt Trigger

Section	Symbol	Type	Function
40 MC Counter	V2101	5963	Decimal Counter Circuit (5 each used)
	V2102	5963	Decimal Counter Circuit (5 each used)
	V2103	5963	Decimal Counter Circuit (5 each used)
	V2104	5963	Decimal Counter Circuit (5 each used)
100 MC Counter	V3101	5963	Decimal Counter Circuit
	V3102	5963	Decimal Counter Circuit
	V3103	5963	Decimal Counter Circuit
	V3104	5963	Decimal Counter Circuit

Frequency Converter 14-21 C

Section	Symbol	Type	Function
	V1, V2	6AH6	Tuned Amplifier
	V3, V4	5725/6AS6W	Balanced Mixer
	V5	6AH6	Harmonic Generator
	V6, V7	6AH6	Video Amplifier
	V8	6E5	Tuning Eye

Time Interval Unit 14-24 I

Section	Symbol	Type	Function
	V601	5963	Stabilized Amplifier (2 used)
	V602	5654/6AK5W	Schmidt Trigger (2 each used)
	V603	5654/6AK5W	Schmidt Trigger (2 each used)

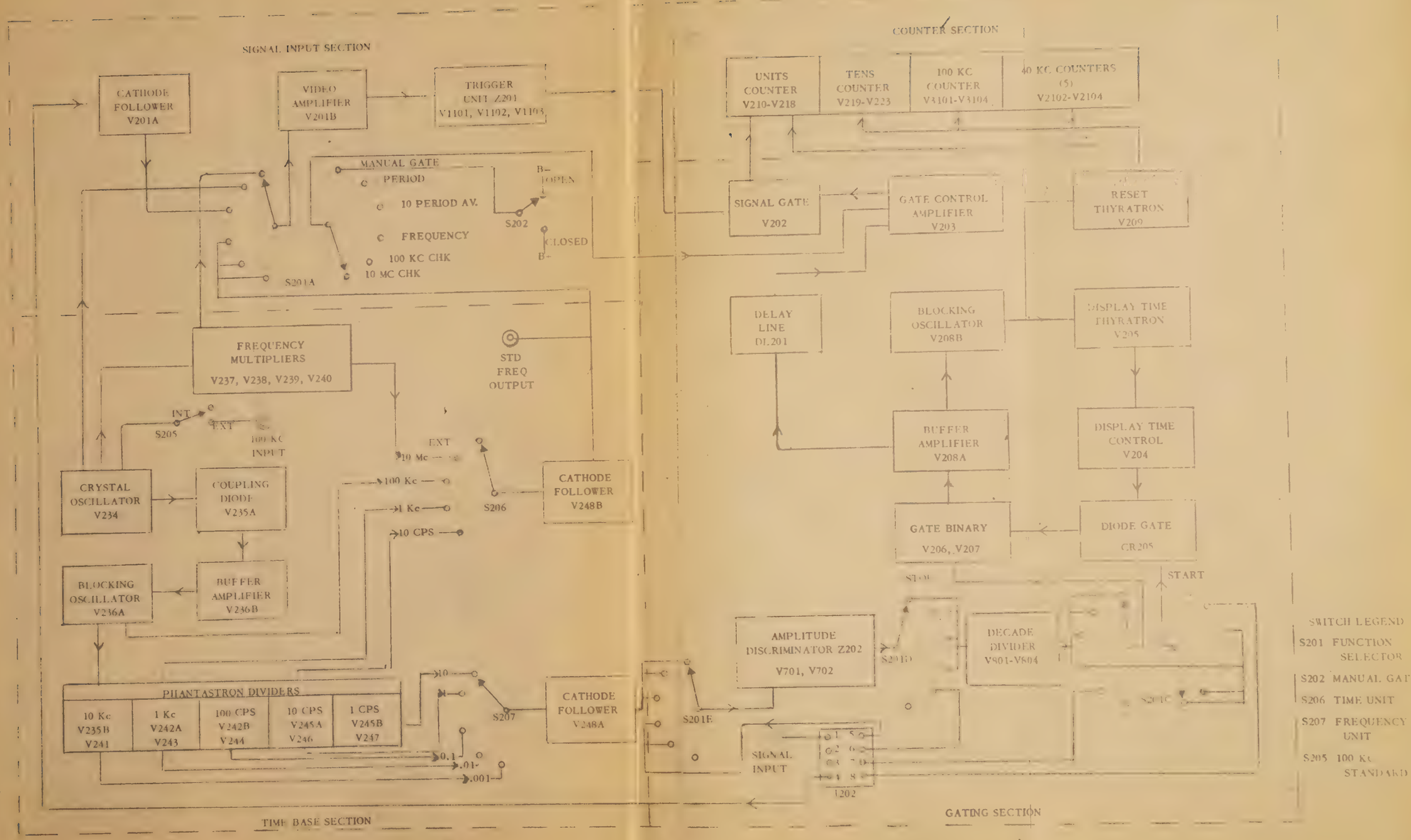


Figure 2. Block Diagram Frequency Counter 14-20 FM.

CHAPTER 2

THEORY OF OPERATION

I. INTRODUCTION.

An overall block diagram showing the major components and their tube components is given in figure 2. The major switching operations are also shown in this figure.

In general, the input signal can take one of two possible paths depending upon whether the measurement desired is one of frequency or one of time duration. In frequency measurement, FUNCTION SELECTOR switch in 10 MC CHK, 100 KC CHK or FREQUENCY position, the input signal goes to the counting circuits by way of the Cathode Follower V201A, Video Amplifier V201B, Trigger Unit Z201 through the Signal Gate V202. Signals of known frequency generated in the time base section and selected by the FREQUENCY UNIT switch serve to control the opening and closing of the Signal Gate V202 by action of the gating section circuits and provide the time base for the frequency measurement.

In measurements of time duration, FUNCTION SELECTOR switch in 10 PERIOD AV or PERIOD positions, the input signal controls the opening and closing of the Signal Gate V202 by the action of the gating section circuits. The signals of known frequency, internally generated in the time base section and selected by the TIME UNIT switch actuate the counting circuits and provide the time base for making the time interval measurements.

In manual gate operation, FUNCTION SELECTOR switch in MANUAL GATE position, the input signal must be connected at the STD FREQ OUTPUT connector and goes to the Signal Gate V202 by way of the Video Amplifier V201B and Trigger Circuit Z201. Opening and closing of the signal gate is accomplished manually by the action of the MANUAL GATE switch S202. The time base circuits are not used in this operation.

A brief theory of operation of the individual circuits making up the unit is given in the following paragraphs.

II. TIME BASE SECTION.

The Time Base Section, as its name implies, provides the necessary precision timing circuits with which all measurements are determined. It includes the crystal oscillator, a coupling diode, blocking oscillator, buffer amplifier, a group of frequency multiplier and phantastron divider circuits. The output from this section appears at the TIME UNIT switch S206 and the FREQUENCY UNIT switch S207.

A. Crystal Oscillator. The crystal oscillator circuit, using a 6AU6WA tube V234, is controlled by a 100 Kc crystal inclosed in a constant temperature oven. Its circuit is a modified Pierce circuit. Limited control over its output frequency is obtained by varying the capacitors C294, C295 and C296. The output of the oscillator is fed through coupling diode V235A, 1/2 of a 5726/6AL5W tube, to a blocking oscillator V236A. This tube reduces loading on V234 and provides the necessary isolation from the remaining circuits. It is driven beyond cut-off every cycle, resulting in a sharp pulse output at a repetition rate determined by the 100 Kc oscillator. The coupling diode, V235A by-passes negative going pulses to C299.

B. Frequency Dividers.

The sharp output pulse from V236A is fed to the grid of buffer amplifier V236B and the negative output from this tube drives the input diode in the first frequency divider stage. The voltage across R434 in the cathode circuit of V236B is connected to the 100 Kc position of TIME UNIT switch S206 for use by the counting circuits.

The frequency divider circuits are a series of five, 10 to 1, phantastron divider stages. The operation of each of these stages is the same with one output pulse appearing for every 10 input pulses. Each has an input diode and a type 5725/6AS6W pentode tube operating in a controlled one-shot multivibrator circuit, the time constants of which are adjusted so that the circuit is retriggered after every tenth input pulse. Output is taken from the cathodes of each of the pentodes (V241, V243, V244, V246 and V247) by the FREQUENCY UNIT switch S207 for use by the gating circuits. Output is also taken from the 2nd and 4th stages for the 1 Kc and 10 cycle signals for TIME UNIT switch S206.

C. Frequency Multipliers.

Output from the 100 Kc oscillator is also fed to the FUNCTION SELECTOR switch S201 for the 100 KC CHK signal and to a frequency multiplier circuit consisting of four tubes V237, V238, V239 and V240. Each stage operates essentially in the same manner, as an overdriven Class C amplifier having nearly square current waveform that is rich in harmonics. The first stage, V237, has a tuned plate circuit, L212 and C307, tuned to the 4th harmonic of 400 Kc. The second stage V238 has a tuned plate circuit, L214 and C311 tuned to the 5th harmonic of 2 Mc. The third stage V239 has a tuned plate circuit, L216 and C315 also tuned to the 5th harmonic of 10 Mc. The output of the 4th stage provides the 10 Mc signal for the 10 MC CHK position of the FUNCTION SELECTOR switch S201. Output from this stage also provides the 10 Mc signal for the TIME UNIT switch S206.

D. Output Circuits.

The TIME UNIT switch S206 passes the selected frequency to a conventional cathode follower circuit using tube V248B. The relatively low impedance output of this tube is delivered to both the STD FREQ OUTPUT connector J205 on the front panel and to the 10 PERIOD AV, PERIOD and MANUAL GATE connections on the FUNCTION SELECTOR switch S201.

The frequencies available at switch S206 (and also at the STD FREQ OUTPUT connector) are 10 cps, 1 Kc, 100 Kc and 10 Mc. These values were chosen to enable the counter readings to express directly, convenient time units when the equipment is used to measure periods or time intervals. Thus a 10 cps frequency would give basic time unit of seconds, 1 Kc and 100 Kc frequencies a basic time unit of milliseconds (with proper positioning of the decimal point) and the 10 Mc frequency a basic time unit of microseconds.

The FREQUENCY UNIT switch, S207 passes the selected frequency to the grid of V248A, also used as a cathode follower. The output voltage taken across R485 is coupled to the amplitude discriminator Z202, by switch S201, section E, and is used to control the gating circuits.

The frequencies available at S207 are 1 cps, 10 cps, 100 cps, 1 Kc and 10 Kc. These values were chosen to give standard gate times of 10 seconds, 1 second, 0.1 seconds, 0.01 seconds, and 0.001 seconds. This enables the counters to express the frequency value directly with no computation necessary when measuring frequency values.

III. AMPLITUDE DISCRIMINATOR AND DECADE DIVIDER.

Output from V248A in the Time Base Section when measuring frequency, or input from the SIGNAL INPUT receptacle when measuring period, is fed to the amplitude discriminator. This is a plug-in unit consisting of two tubes V701 and V702. V701 acts as a two-stage direct coupled amplifier, one half of V701 operating as the first stage with a gain of unity and the other half as a linear amplifier. The output of this stage is directly coupled to the grid of V702 used in a Schmitt Trigger circuit. This circuit is a cathode-coupled bistable multivibrator. Transition between the two stable states is dependent on the input voltage from V701. A change in level at the input of approximately 1 volt is sufficient to trigger the circuit and produce an output signal.

The output signal produced is fed through section S201D of the FUNCTION SELECTOR switch to the decade divider consisting of the tubes V801 to V804 inclusive. When the FUNCTION SELECTOR switch is in the PERIOD position the decade divider is by-passed, the signal going directly to the gating section. The decade divider is a four stage binary counter circuit whose operation is basically the same as the decade counters in the counter section except that no indicating lights are needed. An output of one pulse for every ten input pulses is provided by the decade divider regardless of input frequency.

IV. GATING SECTION.

The gating section opens and closes the triggering circuits to the counters, controls the display time and provides the reset pulse to clear the counters.

A. Gate Binary and Diode Gate.

The differentiated output from the decade divider or the output from the amplitude discrinimator is applied through section C of S201 to the diode gate CR205 and on to the gate binary, V206 and V207 connected in a modified Eccles-Jordan flip-flop circuit. The gate binary provides the voltages which open and

close the signal gate V202, the signal gate being held open for the time interval between the negative start and stop pulses to the gate binary. Bias voltage on the diode gate CR205 furnished by display time circuits prevent the triggering pulse from reaching the gate binary during the display time cycle.

The accuracy of the gate period depends on the speed of the flip-flop circuit. To increase this speed, diodes are used to clamp the grid and plate circuits to limit the voltage through which the grids and plates must swing to trigger the binary from one state to the other. Plate voltages go from +70 to+90 volts. When the voltage on the plate of V207 is +70 the gate is open and when it is +90 the gate is closed.

B. Buffer Amplifier.

Output from the plate of V207 is applied to the grid of the buffer amplifier V208A which serves to prevent excessive loading of gate binary and to provide low-impedance output to the delay line DL201. Two outputs are taken from this tube, one from the plate and the other from the cathode.

C. Delay Line and Gate Control Amplifier.

The negative pulse from the cathode of the buffer amplifier V208A is passed through the delay line DL201 to the gate control amplifier V203. The negative going pulse on the grid of V203 allows the plate voltage to reach that set by the +90 volt clamp. This potential is applied to the suppressor grid of the signal gate V202 which opens the gate. Positive-going pulse reduces the plate voltage to the +70 volt level cutting off V202 and closing the gate.

The function of the delay line DL201 is to introduce sufficient time delay in the signal from the buffer amplifier to enable the transients arising from the counter reset circuits to die down before the signal gate is opened.

D. Signal Gate.

The signal gate tube V202 is a type 5725/6AS6W which is specially designed for gating purposes. Its suppressor grid is closely wound and is used as a second control grid for the tube. A voltage of +70 volts on this grid effectively cuts off from the plate any signal impressed on the first control grid whereas at a voltage of +90 volts the tube will function as an amplifier. The signal normally applied to the first control grid is the signal under test. A neon lamp I201 in the gating circuit, marked GATE, indicates the condition of the circuit, on when the gate is open and off when it is closed.

When the FUNCTION SELECTOR switch is in MANUAL GATE position the grid voltage on the gate control amplifier is shifted from positive to negative by the action of the MANUAL GATE switch S202, controlling the operation of this tube which in turn controls the gating tube V202.

E. Reset and Display Time Circuits.

The signal taken from the plate of the buffer amplifier V208A is applied to the grid of the blocking oscillator V208B. The output of V208B is coupled by transformer T201 to the grids of both the reset thyratron V209 and the display time thyratron V205. These thyratrons are fired simultaneously. The negative pulse from the plate of V209 is used to reset the 1 Mc counter circuit. The positive pulse from the cathode of V209 is used to reset the decade counters and 10 Mc counter circuit.

The display time circuit consists of the display time control tube V204 in a Schmitt Trigger circuit and the display time thyratron V205. Display time may be controlled automatically by the start and stop pulses or manually to give any desired length of display time.

In automatic control, when V205 is fired, capacitor C216 is discharged cutting off one half of V204 and allowing the other half to conduct, placing a closing bias on the diode gate CR205. Capacitor C216 slowly recharges at a rate set by DISPLAY TIME control variable resistor R237. When C216 is sufficiently charged V204 returns to its original condition and diode gate reopens to accept the next start pulse. The time interval for this operation can be adjusted continuously from 0.1 seconds to approximately 5 seconds by the DISPLAY TIME control.

In manual control the DISPLAY TIME is placed in INF position actuating switch S203. This places a bias voltage on one grid of V204 which is approximately midway in the triggering voltage range. Pushing the RESET button charges capacitor C220A. Releasing the RESET button allows C220A to discharge through R244 and R242 resulting in a positive pulse applied to the first grid of V204 sufficient to trigger the circuit and open the diode gate CR205. This pulse is also used to reset the gate binary and the decade divider to accept the next input pulse. The resulting positive pulse from the gate binary fires thyra-

tron V205 which in turn retriggers V204 to close the diode gate CR205. This condition is maintained until the RESET button is pushed.

IV. SIGNAL INPUT SECTION.

Signals connected to the SIGNAL INPUT receptacle J203 are fed to the grid of V201A. Output voltage is taken from the cathode across R204 and passed to a video amplifier V201B through the FUNCTION SELECTOR switch section S201A when the switch is in the FREQUENCY position. The output from the plate of V201B is used to operate the trigger unit Z201 consisting of the tubes V1101, V1102 and V1103. This circuit operates much the same as the amplitude discriminator (see paragraph III). Circuit changes, however, present in Z201 enable it to respond to faster pulses. The first stage V1101 acts as a two stage amplifier, V1101A and V1101B, with unity gain in the first stage to stabilize the circuit. The second stage consisting of V1102 and V1103 is connected in a Schmitt trigger circuit. Output from this circuit is applied to the control grid of the signal gate tube V202.

V. COUNTING CIRCUITS.

There are eight decade counter circuits, one for each place in the count display. Each decade counter gives one output pulse for every ten input pulses and displays the number left over, in this division by ten, on an indicating device. The first two places, the units place and the tens place, are shown on meters and the remaining six places are shown on a series of ten neon indicating lights marked from 0 to 9, one such series for each place.

Each of the decade counters is made up of four binary scaler stages. The basic binary scaler circuit is is an Eccles-Jordan trigger circuit which normally gives one output pulse for every two input pulses. Four such circuits connected in cascade would result in one final output pulse for every sixteen input pulses. To make the circuit operate with the desired 1 to 10 ratio (rather than 1 to 16) feedback between circuits is employed to effectively advance the operation of the circuits so that recycling occurs and an output pulse appears after every ten input pulses. The output pulse from each decade counter is fed to the next decade counter in line, the operation of all counters being basically the same. However, because the first stage, or units decade counter, has to count at a much faster rate, circuit constants differ considerably in this unit. To accomplish this faster counting, high Gm pentode tubes are used (two type 6AH6 and two type 6SB6) and stray capacitances are minimized. Secondly, the grids as well as the plates are provided with diode clamps to limit the necessary grid swing to approximately 2 volts and the plate swing to approximately 20 volts to initiate triggering. Thirdly, a high speed feedback circuit is used.

The second stage, or tens decade counter, not having to count so rapidly, has a simpler circuit using four type 5963 tubes. In each of these decade circuits the output is fed to a meter whose deflection is proportional to the residual count in the decade. A resistance network is provided with proper choice of resistors to center the meter pointer at the digit on the meter representing the count. Zero center meters are used, the pointer resting at a point between 4 and 5 with zero current. Better tracking is possible with this type of meter.

The remaining six decade counters are all replaceable plug-in units. Five of these Type 140-40, are exactly alike and interchangeable with each other. The sixth, Type 140-100, which immediately follows the tens counter in the circuit has different circuit components to decrease its response time somewhat although basically the circuits are all the same in all six units. They each use four binary scaler circuits using 4 each, type 5963 tubes. Two feedback circuits, from the third stage to the second and from the fourth to the third, are used to provide the required division by ten feature. The residual count is displayed on a series of ten neon lamps marked from 0 to 9 within the unit and visable through slots in the front panel of the main unit.

The position of the decimal point is set by the combined action of the FUNCTION SELECTOR switch S201 and the TIME UNIT switch S206 or FREQUENCY UNIT switch S207 as required.

VI. POWER SUPPLY.

All necessary operating voltages are provided by the power supply which operates from a 115 volt, 50-1000 cps power source. In addition to the necessary filament voltages, five different operating voltages are supplied by two separate full wave rectifier circuits, one for positive voltages and one for negative voltages.

The negative voltage of −195 volts is supplied by a 5Y3WGTA tube V257 followed by two 6005/6AQ5W tubes V258 and V259 in a series regulator circuit controlled by a 6AU6WA tube V260. The voltage reference point is maintained by the reference tube V261, a type 0B2WA.

Four positive voltages are supplied by the three 5R4WGY tubes, V249, V250 and V251 connected in parallel. Part of the output from this rectifier circuit is filtered and used to provide approximately +300 volts unregulated dc voltage.

The balance of the output is used to provide three regulated voltages, +210, +90 and +70 volts. Regulation for the +210 voltage is provided by V253 and V254, both type 6080WA, controlled by V252. Regulation for the +90 voltage is provided by one half of V254 controlled by one half of V256 and for the +70 voltage by the other half of V254 controlled by the other half of V256. The voltage values are controlled with respect to the −195 volt bus rather than ground. The effect of this is to maintain a constant voltage ratio between the voltages used rather than a constant voltage value. This is very important for proper operation of the various triggering and flip-flop circuits in the unit.

Adjustment controls are provided for each output voltage:- R524 for the −195 volt supply, R501 for the +210 volt supply, R509 for the +90 volt supply and R516 for the +70 volt supply. For the setting of these controls see section on Adjustment.

The crystal oven heater and space heaters R490, R491 and R492 operate directly from the 115 volt ac input line. A separate winding on the power transformer T205 provides the power for the rectifier CR260 which operates the blower motor B201.

VII. FREQUENCY CONVERTER UNIT 14-21 C.

The Frequency Converter Unit is used to extend the frequency measuring range of the basic unit to 100 Mc. It consists of two tubes, V1 and V2, in a push-pull tuned amplifier circuit, two tubes, V3 and V4, in a balanced mixer circuit, V5 as a harmonic generator driven by a 10 Mc input signal supplied by the basic unit, V6 and V7 as a two stage video amplifier and V8 as a tuning eye to assist in determining the proper setting for the controls.

Tuning for the input signal is accomplished by a coarse adjustment TUNING RANGE-MC switch S2 divided into three ranges 10-20, 20-40 and 40-100 Mc and a fine TUNING control which varies capacitor C12 in the plate circuit of the tuned amplifier. The tuned output is fed to the control grids of the balanced mixer where it beats with the output from the harmonic generator selected by the MIXING FREQUENCY switch S1 and applied to the suppressor grids of the balanced mixer. Switch S1 is calibrated in steps of 10 from 10 to 90, representing successive harmonics of the fundamental 10 Mc signal on the grid of V5. The output beat frequency, which is something less than 10.0 Mc, is amplified by the two stage video amplifier and fed to the basic unit where it is measured in the accustomed manner. The measured frequency will be the sum of the MIXING FREQUENCY switch setting in megacycles and the counter reading in kilocycles.

When switch S1 is in 0 position the input signal to the basic unit is fed directly to the input of the two stage video amplifier, V6 and V7. The rest of the circuits of the frequency converter are inactive. This allows the converter to be used as a straight amplifier with signals of 10 Mc or lower frequency.

VIII. TIME INTERVAL UNIT.

The Time Interval Unit 14-21I provides two separate input channels for controlling the gating circuits in the basic unit. One channel is used for a starting signal to open the gate, the other for a stopping signal to close the gate. During the period of time that the gate remains open, a signal of known frequency, selected by the TIME UNIT switch S206 from the time base section, is counted and displayed on the counters as a function of time (see paragraph II D). The counters will thus record the time duration between the start and stop signals.

Each channel is identical. There are two controls in each, a TRIGGER LEVEL-VOLTS control and a TRIGGER SLOPE control. The TRIGGER LEVEL-VOLTS control has two sections S202 and R110, one for coarse adjustment and one for fine adjustments. A voltage level from −190 volts to +190 volts can be selected by these controls for the triggering voltage to be supplied. The TRIGGER SLOPE control S105 selects between positive going or negative going pulses. The two controls thus give a choice of four possible combinations of triggering voltages, positive voltage with positive slope, positive voltage with negative slope, negative voltage with positive slope or negative voltage with negative slope. Identical trigger units in each channel composed of the three tubes V601, V602 and V603 in a combination amplifier-

trigger circuit, serves to shape the output pulses into suitable form for the gate binary circuits in the basic unit. These trigger units are very similar in circuitry and operation to the trigger unit Z201 (see paragraph IV).

A switch S102, marked SEP-COM is provided to enable choice between start and stop signals from the same or different sources. S102 in the COM position ties the two channels together and the input signal can be connected to either input receptacle. In the SEP position two separate signal sources are required, one to start and the other to stop the counting action.

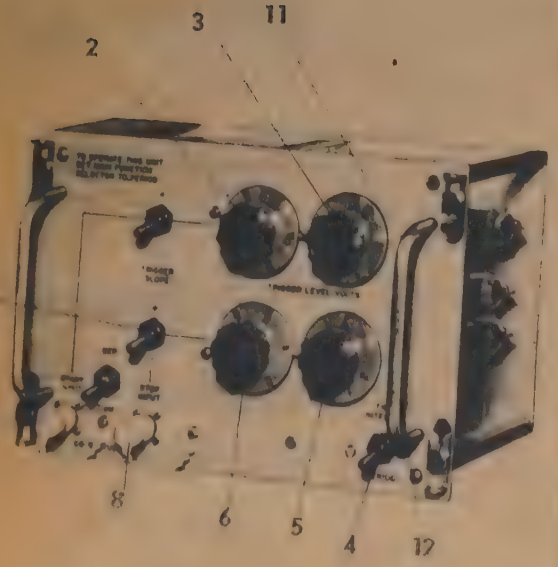


Figure 4. Operating Controls,
Time Interval Unit.

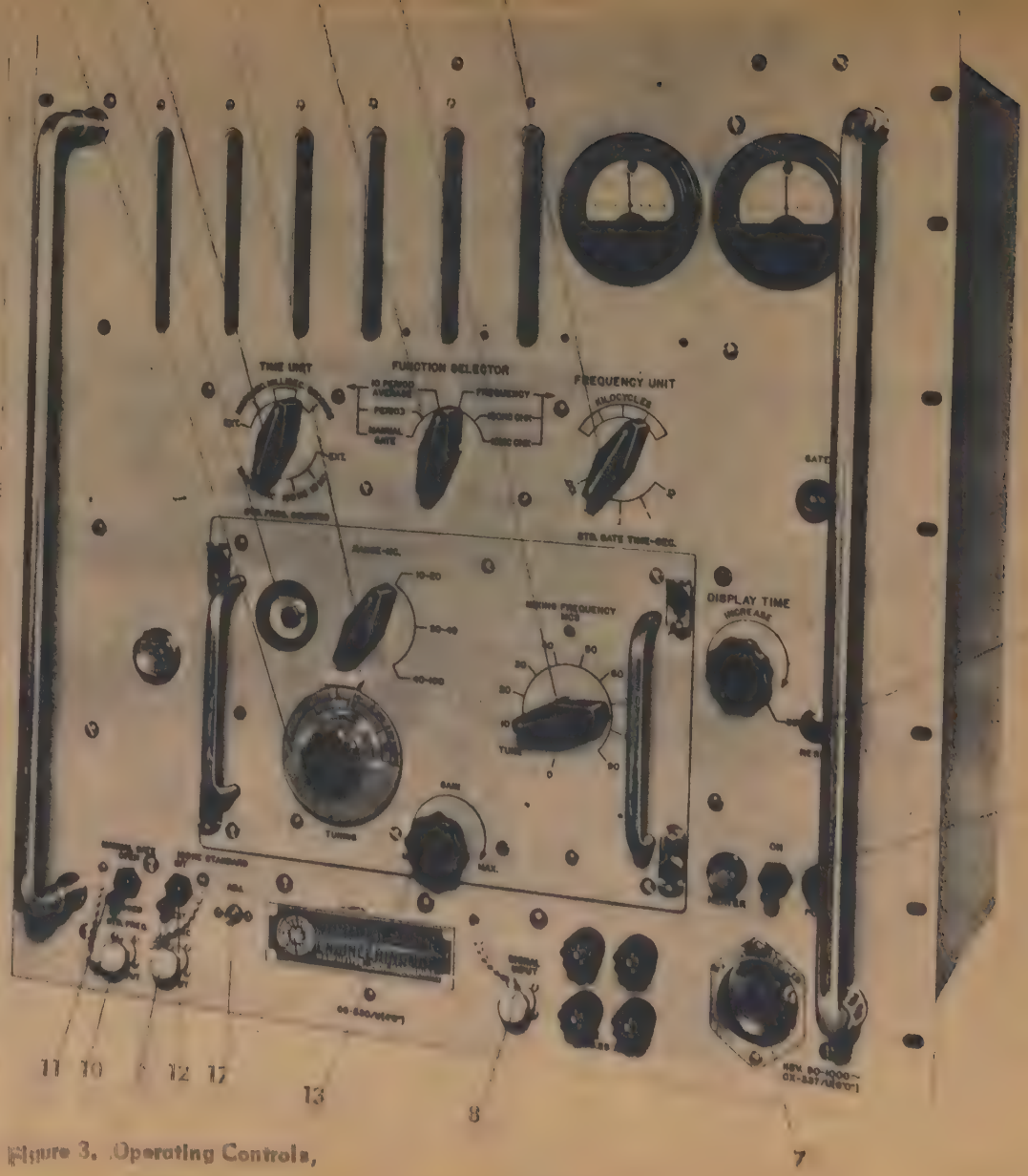


Figure 3. Operating Controls,
Frequency Counter and Frequency Converter.

CHAPTER 3.

OPERATION

I. OPERATING CONTROLS AND CONNECTIONS.

The following constitute the operating controls with their function and are all located on the front panels of the units.

A. Basic Unit (figure 3).

1. TIME UNIT-STD FREQ COUNTED (1) - selects standard frequency to be counted. Used with ten period average, period, manual gate and time interval measurements.

2. FUNCTION SELECTOR (2) - selects the type of operation desired.

3. FREQUENCY UNIT-STD GATE TIME (3) - selects standard gate time. Used in frequency measurements and self-check.

4. DISPLAY TIME (4) - adjusts length of display time from 0.3 to 5 seconds. INF setting will give continuous display.

5. RESET (5) - returns counters to zero with manual gate operation. Recycles counter with continuous display.

6. ON (6) - power switch. Upper ON position energizes all circuits, down position energizes space heaters and crystal oven only.

7. 115v 50-1000 (7) - Input connector for AC power.

8. SIGNAL INPUT (8) - input connector for signal under measurement (except time interval and totalizing measurements).

9. 100 KC-INPUT (9) - connector for using external 100 Kc standard frequency.

10. STD FREQ-OUTPUT (10) - output connector at which appears standard frequency selected by TIME UNIT-STD FREQ COUNTED control (1).

11. MANUAL GATE (11) - open or close gating circuit with FUNCTION SELECTOR control (2) in MANUAL GATE position.

12. 100 KC STANDARD (12) - selects between the internal frequency standard or an external frequency standard for operation.

B. Frequency Converter Unit 14-21C (figure 3).

1. GAIN (13) - adjusts gain of amplifier for proper output level.

2. TUNING (14) - tuning control.

3. RANGE- MC (15) - range selector for TUNING control (14).

4. MIXING FREQUENCY (16) - selects proper mixing frequency to obtain frequency output from the converter of less than 10 MC.

C. Time Interval Unit 14-21 I (figure 4).

1. TRIGGER SLOPE (1) - selects between positive (+) and negative (−) going signals to trigger start channel.

2. TRIGGER LEVEL VOLTS (2) - multiplier control for TRIGGER LEVEL VOLTS (3) control.

3. TRIGGER LEVEL VOLTS (3) - adjusts start channel (with 2) to trigger between −200 and +200 volts.

4. TIME INTERVAL-PERIOD (4) - selects between use for measuring time interval or period.

5. TRIGGER LEVEL VOLTS (5) - adjusts stop channel (with 6) to trigger between −200 and +200 volts.

6. TRIGGER LEVEL VOLTS (6) - multiplier control for TRIGGER LEVEL VOLTS (5) control.

7. TRIGGER SLOPE (7) - selects between positive (+) and negative (−) going signals to trigger stop channel.

8. STOP INPUT (8) - connector for input of stopping signal.

9. SEP-COM (9) - selects between start and stop input connectors (8 and 10) connected together (COM position) or separated (SEP position).

10. START INPUT (10) - connector for input of starting signal.

II. INSTALLATION.

The Frequency Counter may be removed from its cabinet and rack mounted in a standard 19 inch relay rack or placed on a bench or table in its cabinet. Power connections are made to the receptacle on the front panel marked 115v 50 - 1000 cycles with the provided power cord. A power supply capable of furnishing 500 watts is needed to operate the unit. When power connections are made the space heater circuits and crystal oven are energized.

III. OPERATION.

A. Warm-up period.

In order to obtain maximum accuracy it is imperative that all circuits reach proper operating temperature before using the unit. When unit is first connected (or reconnected after period of non-use) to the power source, allow about two hours for the crystal to be heated thoroughly. Watch the thermometer in the crystal oven to see that it indicates within the green area. If temperature rises above this area disconnect power and investigate trouble source. If the unit is being regularly used always keep power cord connected to the power source (space heater and crystal oven energized. HEATER pilot light on).

When power switch is turned ON (POWER light energized) allow 15 minutes for circuits to stabilize before making measurements.

B. Self-Check.

A built-in self-checking feature provides a check on the operation of most of the circuits in the basic unit. One of the plug-in units should be in place while making the check. If the basic unit is being used without a plug-in unit then the special plug shall be used to terminate the 8 terminal receptacle in the opening in the front panel.

NOTE

Whenever a plug-in unit or the special plug is removed or replaced the power switch should be in the down position (POWER light off) to prevent arcing at the connector receptacle.

1. Turn power switch (6) ON. Allow at least 5 minutes warm-up time.

2. Set MANUAL GATE (11) to CLOSED position and 100 KC STANDARD (12) switch to INT position.

3. Set FUNCTION SELECTOR (2) to 100 KC CHECK position.

4. Set DISPLAY TIME (4) control to desired position, usually extreme counterclockwise. If INF position is used it will be necessary to reset counters with RESET (5) button between readings.

5. Set FREQUENCY UNIT (3) switch to 10 SEC on STD GATE TIME scale. Counters should record 0100.0000.

6. Check with FUNCTION SELECTOR (2) in 10 MC CHECK position. Counters should record 0000.0000 ± .0001.

7. Repeat at each setting of the FREQUENCY UNIT (3) switch at each of the two positions, 100 KC CHECK and 10 MC CHECK, of the FREQUENCY SELECTOR switch. The results obtained should agree with the following table:-

GATE TIME	100 KC CHECK	10 MC CHECK
10. sec	0100.0000	0000.0000 ± .0001
1. sec	00100.000	10000.000 ± .001
0.1 sec	000100.00	010000.00 ± .01
0.01 sec	0000100.0	0010000.0 ± .1
0.001 sec	00000100.	00010000. ± 1.

NOTE

The ±1 error in the 10 MC CHECK position is the acceptable operating tolerance of the gating circuits.

8. Correct readings indicate proper functioning of the unit. Discrepancies in the readings indicate trouble with the unit.

9. If trouble with the interval 100 Kc oscillator is suspected or to check on its proper operation an external known 100 Kc signal source may be used.

a. Connect the output from the known 100 Kc signal source to the 100 KC INPUT (9) receptacle.

b. Set 100 KC STANDARD (12) switch in EXT position.

c. Repeat test procedure as outlined above. The same set of readings should result. Correct readings with an external 100 Kc source and incorrect readings with the internal source would indicate trouble in the 100 Kc oscillator circuit.

10. If any inaccuracies are noted in the above checking procedure read Chapter 4, Adjustment and Alignment.

C. Measuring Frequency, 10 cps to 10 Mc.

Frequencies up to 10 Mc may be measured with any of the plug-in units in place and up to 100 Mc with the 14-21 C Frequency Converter. If no plug-in units are available the special plug may be used to terminate the 8 terminal connector is the basic unit. If the 14-21 C Frequency Converter is used a lower input voltage level is permissable - down to 0.2 volt rms. Without this unit a 1 volt rms input level is required.

1. Procedure without use of Frequency Converter unit.

a. Turn power (6) switch ON and allow sufficient warm-up time.

b. Set FUNCTION SELECTOR (2) switch to FREQUENCY position.

c. Connect the signal whose frequency is to be measured to SIGNAL INPUT (8) receptacle. The input impedance at this receptacle is approximately 1 megohm shunted by 40 mmf. Noise level should be less than 10 millivolts. Unstable counter readings could result from too high a noise level or insufficient signal.

d. Set FREQUENCY UNIT (1) switch to desired gate time. A 10 SEC gate time gives the most accurate readings.

e. Set DISPLAY TIME (4) control to desired display time. If INF position is used count will be continuously displayed until reset by RESET (5) button. A minimum display time combined with a short gate time will give continuous display with a sacrifice in accuracy. This setting is useful in making tuning adjustments on equipment.

NOTE

The display time cannot be adjusted to be less than the gate time.

f. Read the frequency on the counters.

2. Procedure with Frequency Counter 14-21 C.

a. Repeat steps a through e in paragraph 1 above.

b. Set MIXING FREQUENCY (16) switch to 0 position.

c. Adjust GAIN (13) control until tuning eye just closes.

d. Read the frequency on the counters.

D. Measuring Frequency, 10 Mc and 100 Mc.

To measure frequencies between 10 and 100 Mc the Frequency Converter 14-21 C must be used. However, the signal input level may be as low as 0.02 volts rms with this unit used in this range.

1. Repeat steps a through e in paragraph C, 1 above.

2. Set MIXING FREQUENCY (16) switch to TUNE. The unit in this position is set to indicate the approximate value of the frequency being measured.

3. Set GAIN (13) control maximum clockwise, maximum gain position.

4. Set RANGE-MC (15) switch to 10-20 position.

5. Starting at low frequency end (near 10 position) tune the TUNING (14) control through its range watching tuning eye (17) for position of minimum shadow. Reset RANGE-MC switch as required. If the image on the tuning eye overlaps reduce GAIN (13) control and retune.

6. Note setting of TUNING dial and RANGE-MC switch when tuning eye is at minimum shadow. Set MIXING FREQUENCY (16) control to the frequency indicated by the TUNING dial making sure to read scale of tuning dial corresponding to the setting of RANGE MC switch.

7. Adjust GAIN control until tuning eye just closes but does not overlap.

8. Read counters. Unknown frequency is obtained by adding the reading on MIXING FREQUENCY (megacycles) to counter reading (kilocycles).

9. Special procedure when frequency is at or near the dividing lines on the TUNING dial.

a. Make reading with MIXING FREQUENCY control at the position of lower frequency. For example:- if TUNING control is at or near dividing line between 40 and 50 make reading with MIXING FREQUENCY control at 40.

b. Repeat with MIXING FREQUENCY control at position of next higher frequency, for example at 50. A comparison of the two results will indicate the correct frequency. To illustrate, if, with the MIXING FREQUENCY control set at 50, a counter reading of 50000 Kc were obtained it would not necessarily follow, that the correct frequency was 50.05 Mc. It could be 49.95 just as well. By using the low setting of 40 the MIXING FREQUENCY the counter reading would be 10050000 Kc if the correct frequency were 50.05 Mc and would be 9950000 Kc if the correct frequency were 49.95 Mc.

E. Accuracy of Frequency Measurement.

The accuracy of the frequency measurement is dependent upon the stability of the internal 100 Kc oscillator and the possible error of ±1 count inherent in the gate and counter type of circuit. In measuring the high frequencies the stability of the oscillator is the limiting factor and at the lower frequencies the ±1 count is the limiting factor. The stability of the oscillator circuit is approximately 2 parts per million per week. If an external 100 Kc oscillator is available with greater accuracy than the internal one, it can be used by connecting its output at the 100 Kc (9) connector on the front panel with the INT-EXT switch (12) in the EXT position.

In terms of counting the accuracy of frequency measurement between 1 Mc and 100 Mc is within 0.0002% ±0.1 cycle with 10 second standard gate time, 0.002% ±1 cycle with 1 second standard gate time and decreasing further as the gate time decreases. Below 1 Mc the accuracy decreases slowly to approximately .001% at 10 Kc when the effect of the percentage error due to the ±1 count causes the accuracy to decrease quite rapidly. At frequencies below 316 cycles per second greater accuracy can be obtained by measuring the period and calcultaing the frequency from the results obtained.

F. Measurement of Period.

Period measurements are made by counting the standard frequencies generated by the time base circuits as the signal under measurement triggers the gating circuits. Circuits are provided to shape the incoming waveform so that triggering takes place at the zero volt crossing of a negative-going voltage. Periods from .0001 sec to 100 sec can be measured.

A choice of measuring one period or the average for 10 periods is provided selected by the FUNCTION SELECTOR (2) switch. The standard frequency used for the time base can be either 10 Mc, 100 Kc,

1 Kc or 10 cps and is selected by the TIME UNIT (1) switch. These frequencies correspond to time units of 0.1 microseconds, 0.01 milliseconds, 1 millisecond and 0.1 second.

Measuring the period is a much more accurate way of determining the frequency of low frequency signals and can be used to measure frequencies as low as 0.01 cps. The greatest accuracy occurs when using the internal frequencies which gives the greatest number of counts over a ten period average.

Period can be measured with either plug-in unit in position or with the special plug terminating the 8 terminal connector in the opening in the front of the basic unit.

1. Procedure for Measuring Period.

a. Turn power (6) switch ON and allow warm-up time.

b. Set FUNCTION SELECTOR (2) switch to PERIOD or TEN PERIOD AVERAGE as desired.

c. Set TIME UNIT (1) switch to desired time me asuring unit.

d. If the Time Interval Unit No. 14-211 is used set TIME INTERVAL-PERIOD (4) switch to PERIOD position.

e. Set DISPLAY TIME (4) control to desired display time.

f. Remove cable from STD FREQ OUTPUT (9) connector if it is in use, to prevent unwanted loading of the internal standard frequency circuits.

g. Connect the input signal to SIGNAL INPUT (8) connector. The input signal level should be between 1 and 200 volts rms.

h. Read period on the counters. Time unit will be as selected by TIME UNIT switch.

2. Accuracy of Period Measurements.

Errors in measuring period for frequencies below approximately 300 cps may be caused by imperfect triggering action. These errors decrease with increase in voltage input. With a 1 volt rms sine wave input they cause a percentage error of ±0.3% in the measurement of one period and ±0.03% in the measurement of the 10 period average with either the 10 Mc, 100 Kc or 1 Kc time base. The percentage of error increases as the period time decreases becoming as high as 0.1% for the ten period average and 10% for the single period at frequencies of 1 Mc with a time base of 10 Mc.

G. Measuring Total Events.

The Frequency Counter is capable of counting electrical events which have a waveform with a rise time of at least 1 millisecond and an amplitude of from 1.5 volts to 10 volts peak and displays the total on the counters. The maximum counting rate is 10 million such events per second and the total count that can be displayed before recycling is 99,999,999 counts. The resolution time is 0.1 microsecond for double pulses and 0.2 microseconds for triple pulses. Either plug-in unit or the special plug to terminate the 8 terminal connector located in the opening in the front panel of the basic unit may be used when totaling.

1. Procedure for Totalizing Events.

a. Turn power (6) switch ON and allow warm-up time.

b. Set FUNCTION SELECTOR (2) switch in MANUAL GATE position.

c. Set TIME UNIT (1) switch in EXT position.

d. Connect signal to be counted to STD FREQ OUTPUT (10) connector.

e. To start count throw MANUAL GATE (11) switch to OPEN position.

f. To stop count throw MANUAL GATE switch to CLOSED position.

g. Read total on the counters. If count exceeds 100,000,000, visual notice of the number of times the counters recycle will have to be made. To clear counters, push RESET (5) button.

H. Measuring Frequency Ratios.

The Frequency Counter may be used to measure the ratio of two frequencies. This is done by applying the higher frequency signal to the counter circuit and using the lower frequency signal to control the gating circuits. Either one or 10 periods of the lower frequency signal can be used to open and close the

gate sellected by the FUNCTION SELECTOR. The counter will then indicate the number of cycles of the higher frequency signal allowed to pass which will be the number of cycles per cycle (or per 10 cycles) of the higher frequency signal with respect to the one of lower frequency. Any plug-in unit or the special termination plug may be used when measuring frequency ratios. If the No. 14-21 I Time Interval unit is used the TIME INTERVAL-PERIOD switch on its front panel must be in the PERIOD position.

1. Procedure for Measuring Frequency Ratio.

a. Set FUNCTION SELECTOR (2) switch to PERIOD or 10 PERIOD AVERAGE as desired.

b. Set TIME UNIT (1) switch to EXT position.

c. Set DISPLAY TIME (4) control to desired display time.

d. Connect input signal with higher frequency to STD FREQ OUTPUT (10) connector on front panel. This signal must be between 10 cps and 10 Mc in frequency, have a rise time of at least .1 millisecond and an amplitude between 1.5 and 10 volts peak. Input impedance at this connector is 1 megohm shunted by 100 mmf. If input signal has any dc component a blocking capacitor should be connected in the circuit.

e. Connect input signal with lower frequency to SIGNAL INPUT (8) connector. This signal may have a frequency between 0.01 cps and 10 Kc and an amplitude between 1.5 and 280 volts peak. Rise time is not critical but the maximum accuracy requires fast rise time. Input impedance at this connector is approximately 1 megohm shunted by 40 mmf.

f. Read the count on the counters disregarding the decimal point. This count will be the number of cycles per cycle (or per 10 cycles) of the higher frequency with respect to the lower.

2. Accuracy of Frequency Ratio Measurement.

The same factors which determine period accuracy determine the accuracy of ratio measurement. At small ratios the ± 1 count is the limiting factor. For a ratio of 100 to 1 this factor would result in a 1% error for single period or 0.1% for 10 period measurement. At ratios above 10,000 the accuracy becomes 0.05% in 10 period and 0.5% in 1 period measurements.

I. Measuring Time Intervals.

The measuring of time intervals requires the use of the Time Interval Unit 14-21 I (figure 3). This unit provides two separate identical input channels for starting and stopping the counting circuits. Controls in these input channels provide selection of the point on the wave form at which triggering will occur. The TRIGGER SLOPE switch (1 or ¯) selects between positive going or negative going trigger signals. The TRIGGER LEVEL-VOLTS (2, 3, 5, or 6) determine the voltage at which triggering will occur. The accuracy of these controls is about 20% ±0.2 volts variation in the zero level. This voltage may be either positive or negative selected by the controls. This results in the choice of four possible conditions for triggering in each channel, (1) positive slope with negative voltages, (2) positive slope with positive voltages, (3) negative slope with negative voltages, (4) negative slope with positive voltages. Voltage amplitude adjustment from −200 through 0 to +200 is provided in each condition. Operation of the counting circuits is the same as in period measurement.

1. Procedure for Measuring Time Intervals.

a. Plug Time Interval Unit No. 14-24 I in position in the Frequency Counter.

NOTE

Be sure power is off when removing or inserting plug-in units.

b. Turn POWER (6) switch ON and allow warm-up time.

c. Set TIME INTERVAL-PERIOD switch (4, figure 3) to TIME INTERVAL position.

d. Set FUNCTION SELECTOR (2) switch to PERIOD position.

e. Connect starting signal to START INPUT (10, figure 3) connector and stopping signal to STOP INPUT (8, figure 3) connector. If the same signal is used for both starting and stopping it may be connected to either input connector. These connectors each have an input impedance of approximately 1 megohm shunted by 20-40 mmf. Input circuits in the Time Interval unit are direct-coupled and will pass dc voltages. If dc components are present in the input signals they will need to be compensated for by the

setting of voltage level controls or elinimated by the use of external blocking capacitors in the input circuits. Voltages between 2 and 200 volts peak are required.

f. Set SEP-COM (9, figure 3), switch in the SEP position if separate starting and stopping signals are used and in the COM position if the same signal is being used for starting and stopping.

g. Set TIME UNIT (1) switch to desired time measuring unit. Greatest accuracy occurs with setting which gives highest count on counters.

h. Set DISPLAY TIME (4) control for desired display time.

i. Set TRIGGER SLOPE (1, figure 3) switch in start channel to + (positive going voltage) or – (negative going voltage) as desired.

j. Adjust TRIGGER LEVEL-VOLTS (2 and 3, figure 3) controls in the start channel to the desired triggering level.

k. Set TRIGGER SLOPE (7, figure 3) switch in stop channel to + (positive going voltage) or – (negative going voltage) as desired.

l. Adjust TRIGGER LEVEL-VOLTS (5 and 6, figure 3) in the stop channel to desired triggering voltage level.

m. Read the time interval as displayed on the counters. Time unit will be as selected by the TIME UNIT switch.

NOTE

To eliminate possible errors due to loading of internal standard frequency circuits, have no cable connected to the STD FREQ OUTPUT (10) connector when measuring periods or time intervals.

2. Measuring Time Intervals with External Frequency Standard.

An external frequency source may be substituted for the internal standard frequencies. The basic time unit of the displayed count will depend on the frequency used. This frequency may be chosen to have a special relationship with the time interval being measured to give a reading on the counters in any desired unit of measure which need not necessarily be time.

a. Perform steps a to f of paragraph I, 1.

b. Set TIME UNIT (1) switch to EXT position.

c. Connect external frequency to be used to STD FREQ OUTPUT (10) connector. This signal should have an amplitude between 1.5 and 10 volts peak. If dc components are present they should be filtered out with a blocking capacitor. The impedance at this connector is 1 megohm shunted by 100 mmf.

d. Perform steps h through m paragraph I, 1.

NOTE

Counters will read in units fixed by the external frequency being used.

3. Time Interval Measurements with Complex Waveforms.

With simple waveforms it is comparatively easy to adjust the controls on the Time Interval Unit to give the desired start and stop threshold values. However, with complex waveform more care will be required to assure that starting and stopping takes place at the required point on the waveform. For example, in waveforms with a step characteristic different readings would be obtained if the threshold values were chosen below rather than above the step in the waveform. Preliminary measurements with different settings of the controls can be made and the corresponding measured time intervals noted to indicate the possible presence of discontinuities in the waveform and to aid in determining the proper control setting for the time interval measurement required. It is also very helpful to display the start and stop signals being used on an oscilloscope to determine their waveform as an aid in selecting the proper operating points. Oscilloscope display will also determine whether spurious signals are present with the required signal which might in themselves act as stop and start signals and hence give erroneous measurements.

CHAPTER 4.

ADJUSTMENT AND ALIGNMENT

SECTION I

ADJUSTMENT PROCEDURE

I. GENERAL. This section contains procedure for adjustments that can be readily made with a minimum amount of test equipment to keep the equipment operating correctly. Many of these adjustments are necessary when certain tubes are replaced in the unit. For more complex adjustments and alignment procedure requiring more complicated test equipment and for the replacement of tubes which might upset alignment see Section 2 on Alignment Procedure. The No. 14-20 FM is a precision instrument. The basic circuit upon which this precision depends is the internal 100 Kc crystal controlled oscillator. In order to insure the precision this oscillator should be standardized periodically. Procedure for standardizing the oscillator and making other needed adjustments follows.

II. ADJUSTING POWER SUPPLY VOLTAGES.

Four regulated dc voltage supplies are provided by the power section; −195, +70, +90 and +210 volts. Since many circuits are dependent on proper voltage values, whenever certain tubes are replaced in the power supply or whenever faulty operation of the unit occurs, voltages checks and adjustments should be made. The power supply consists of tubes V249 through V261. Tubes V252, V255, V256, V260 and V261 have a regulatory function and could affect the voltage output values if they are weak or have been replaced. Variable resistors R524, R501, R509 and R516 are used to make these adjustments. These resistors are located on brackets attached to the middle partition of the rear chassis section.

1. Remove the unit from the dust cover by first loosening the four captive screws in the back of the dust cover and then withdrawing the unit from the cover. This allows access to the adjustment resistors.

2. Insert one of the plug-in units or use the special shorting plug if no plug-in units are available.

3. Turn POWER switch on. Allow five minutes warm-up time.

CAUTION

Do not change tubes with power on. Do not turn power on unless all power supply tubes are in their sockets.

4. Measure line voltage. For optimum results in making adjustments it should be 115 volts ± 2%. It should not be less than 105 volts or more than 125 volts.

CAUTION

In connecting the voltmeter into the circuit do not short +70 or +90 volt buses to ground or to the +210 volt bus as damage to most of the crystal diodes will result. Any probe should be completely insulated leaving only the extreme tip end exposed to prevent possible shorting.

5. Adjust R524 first. Connect a high resistance dc voltmeter between ground and pin 7 of V261. This is the −195 volt dc supply and R524 should be adjusted to give a meter reading of −195 volts.

6. Adjust R501 next. This is in the +210 volt dc supply. Connect voltmeter between ground and pin 1 of V255. Adjust R501 for a meter reading of +210 volts.

7. Adjust R509 next. This is in the +90 volt dc supply. Connect voltmeter between ground and pin 6 of V255. Adjust R509 for a meter reading of +90 volts.

8. Adjust R516 last. This is in the +70 volt dc supply. Connect voltmeter between ground and pin 3 of V255. Adjust R516 for a meter reading of +70 volts.

9. Recheck each voltage in the same order and make any further adjustments necessary.

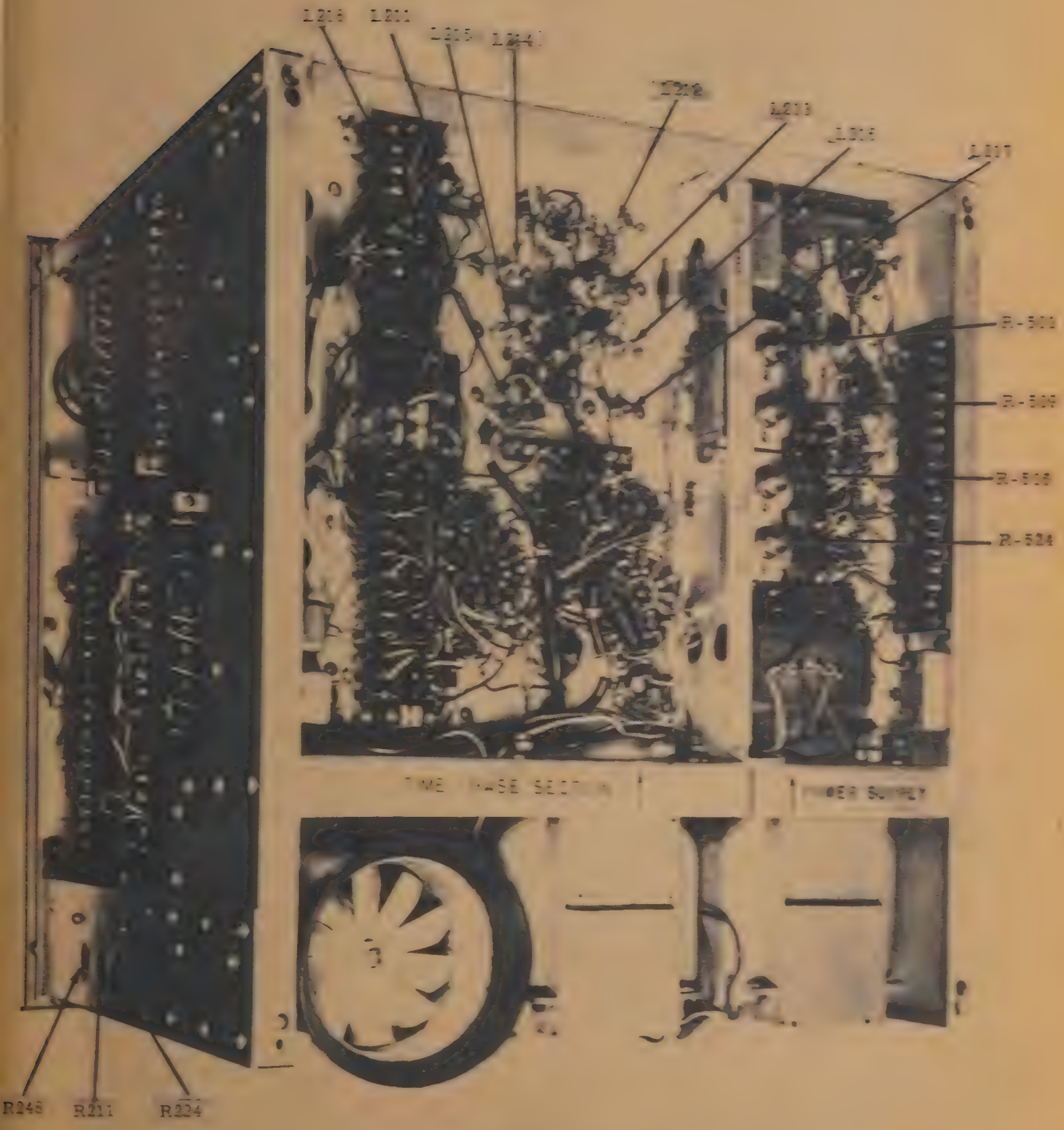


Figure 5. Frequency Counter, Interior.

III. STANDARDIZING THE 100 KC OSCILLATOR.

The 100 Kc oscillator may be standardized by using the unit to measure an external standard frequency whose accuracy is known to be better than its own internal oscillator or by beating the 100 Kc output (or harmonic of it) against the National Bureau of Standards Station WWV. Either method requires that the oscillator reach its optimum stability of ±2 parts per million per week. A period of several days continuous operation is necessary to assure that this condition is met and that the crystal is properly stabilized. The first step is to make sure the equipment is functioning properly by performing the Self-Check procedure. Chapter 2, paragraph III B. Number references in the following refer to figure 3.

A. Procedure Using Known Standard Frequency.

1. Connect a source of known standard frequency in the 1 to 10 Mc range, accurate to 5 to 10 parts in 10,000,000 with an amplitude of at least 1 volt (0.2 volt is sufficient if the Frequency Converter No. 14-22 C is being used) and a signal to noise ratio of at least 40 db to the SIGNAL INPUT (8) terminal.

2. Set FUNCTION SELECTOR (2) switch to FREQUENCY position.

3. Set DISPLAY TIME (4) control fully counterclockwise.

4. Set FREQUENCY UNIT (3) switch to 1 SEC on STD GATE TIME-SEC scale if standard frequency is at or near 10 Mc and to SEC if standard frequency is at or near 1 Mc.

5. Read count as indicated on counters. If it does correctly show the value of the standard frequency adjust the ADJ (17) control with a screwdriver until it does. Pay particular attention to the meter readings in the counter circuit. The lock nut on this control has been factory set to be tight enough to hold the setting but not too tight to prevent turning.

6. Check the reading using other gate times.

B. Procedure Using WWV

A communications receiver is necessary to determine zero-beat using this method.

1. Set TIME UNIT (1) switch to 100Kc.

2. Set 100 KC STANDARD (9) switch to INT.

3. Loosely couple the 100 KC output signal from STD FREQ OUTPUT (10) connector to the communications receiver. A single wire from the connector to close proximity of the receiver antenna lead-in should be sufficient. If more coupling is needed wrap a few turns of wire around the lead-in.

4. Tune the receiver to the WWV frequency which gives an audible beat note with the 100 Kc output. The harmonic output of this oscillator should be sufficient to beat with a frequency as high as 10 Mc.

5. Adjust the ADJ (17) control for zero beat (see paragraph A, 5 above for the adjustment of this control).

IV. ADJUSTMENT OF PHANTASTRONS.

The standard gate times used in frequency measurements are derived from the 100 Kc crystal controlled oscillator by using a series of decade frequency divider circuits known as phantastrons. Circuit constant changes with time may upset the phantastron circuits to the point where division by 9 or 11 is occurring rather than 10. This condition will show up during the self-checking procedure by erroneous display of 9's or 11's on the counters instead of 10's. Variable resistors, R444, R459, R462, R471 and R480, located just inside the upper edge of the opening in the center panel which positions the plug-in units, are used to adjust these circuits. If a plug-in unit is in place turn power off and remove it to allow access to these resistors. The adjustment procedure is as follows:-

1. Turn POWER switch on and allow at least 15 minute warm-up time.

2. Set FUNCTION SELECTOR switch to 100 KC CHECK position.

3. Set FREQUENCY UNIT switch to 0.001 second STD GATE TIME.

4. Set DISPLAY TIME control for minimum display time.

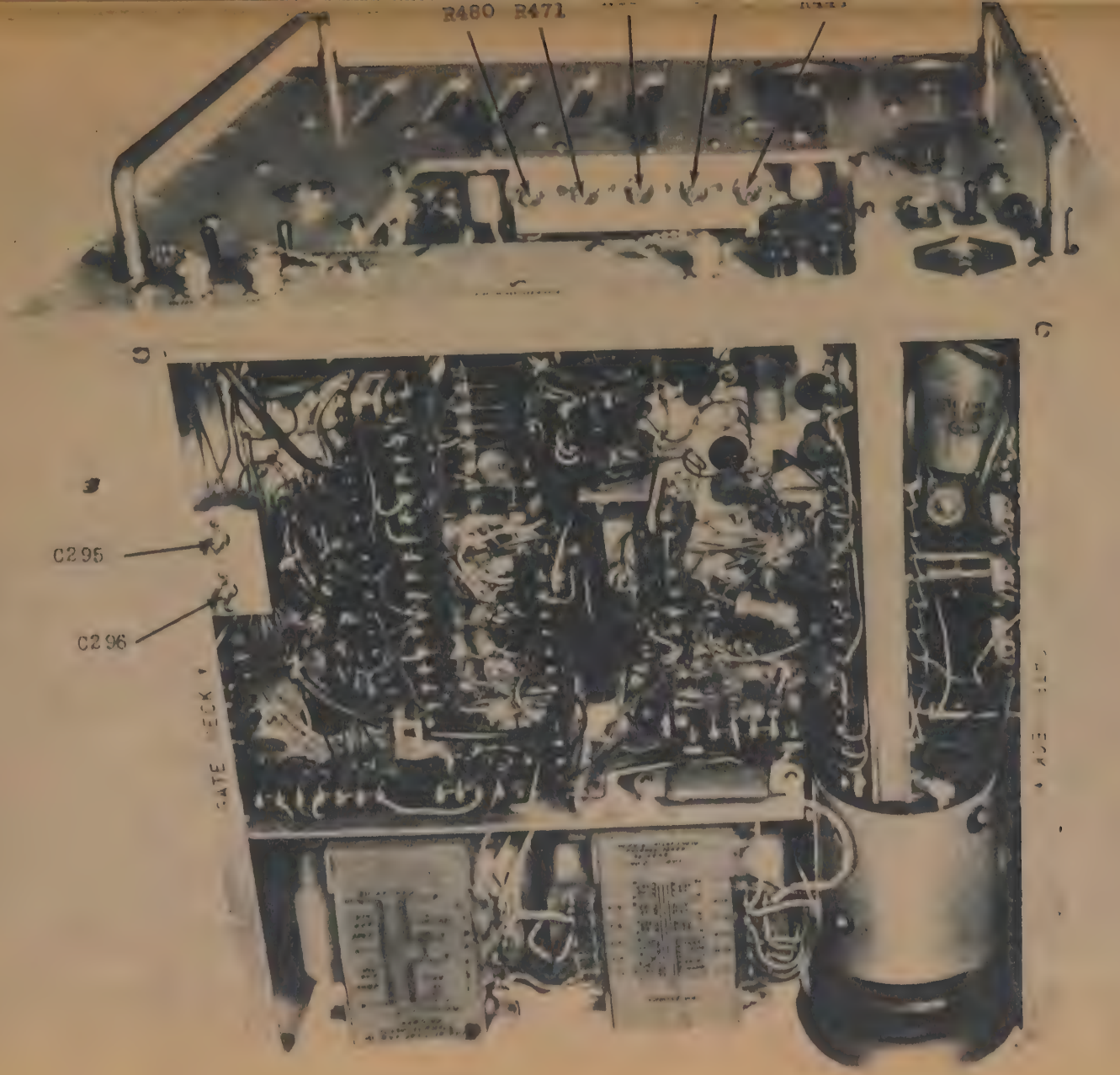


Figure 6. Frequency Counter, Interior.

5. Counter should read 00000100. If it reads 00000080, 00000090, 00000110 or 00000120 the first phantastron circuit is out of adjustment.

6. Adjust R444 to the center of the region which gives a stable counter reading of 00000100. The locknut should allow adjustment but be tight enough to hold the setting once made.

7. Set FREQUENCY UNIT switch to 0.01 seconds STD GATE TIME.

8. Counter should read 0000100.0. If it does not, adjust R453 in the same manner as R444 was adjusted in step 6.

9. Repeat the above procedure for the three remaining positions of FREQUENCY UNIT switch. At 0.1 seconds adjust R462; at 1 second adjust R471 and at 10 seconds adjust R480. Be sure and adjust each variable resistor to the center of the region giving an accurate stable reading.

V. CHANGING TUBES IN THE PHANTASTRON CIRCUITS.

The phantastron circuits include the following tubes V241 to V247 inclusive. It will be necessary to follow the phantastron adjustment procedure of paragraph IV if any of these tubes are changed.

VI. ADJUSTMENT OF GATE LENGTH.

Gate length time is partially dependent on the grid bias applied to gate amplifier tube V203. The variable resistor R224 in the grid bias circuit is used to control the amount of this bias. This resistor, marked GATE LENGTH is located near the lower edge of the right hand side of the chassis. If V203 is replaced or its characteristics change with time R224 should should be adjusted to obtain proper gate length time. It may also be necessary to check the adjustment of R224 when replacing tubes V206, V207 or V208 which are also in the gating circuit.

1. Remove the unit from the dust cover by loosening the four captive screws in the back and withdrawing the unit. This will allow access to R224.

2. Install a plug-in unit or the special shorting plug-in if no plug-in unit is available.

3. Turn POWER switch on and wait at least five minutes for warm-up.

4. Set FREQUENCY SELECTOR switch to 10 MC CHECK position.

5. Set FREQUENCY UNIT switch to 1 second, STD GATE TIME.

6. Adjust GATE LENGTH control R224 until counter reads 10,000,000 ±1. Check after 24 hours of continuous operation and re-adjust if necessary. Locknut tension on R224 should be sifficient to hold the setting but not prevent adjustment.

VII. ADJUSTING TRIGGER UNIT BIAS.

The signal channel trigger unit Z-201 is a plug-in unit located on the gate deck section. It has three tubes V1101, V1102 and V1103. The grid bias on one half of V1101 is adjustable to control the sensitivity of the trigger unit. Incorrect adjustment of this grid bias can cause counting at either half or double the proper rate. The control for this bias is the variable resistor R211 marked FREQ SENS and located near the GATE LENGTH control on the lower edge of the right hand side of the chassis. The adjustment procedure follows:-

1. Remove the unit from the dust cover by loosening the four captive screws in the back and withdrawing the unit. This allows access to R211.

2. Install a plug-in unit or the special shorting plug if no plug-in unit is available.

3. Turn POWER switch on and allow at least 5 minutes warm-up time.

4. Set FUNCTION SELECTOR switch to MANUAL GATE position.

5. Set TIME UNIT switch to 100 Kc position.

6. Throw 100 KC STANDARD switch to INT position.

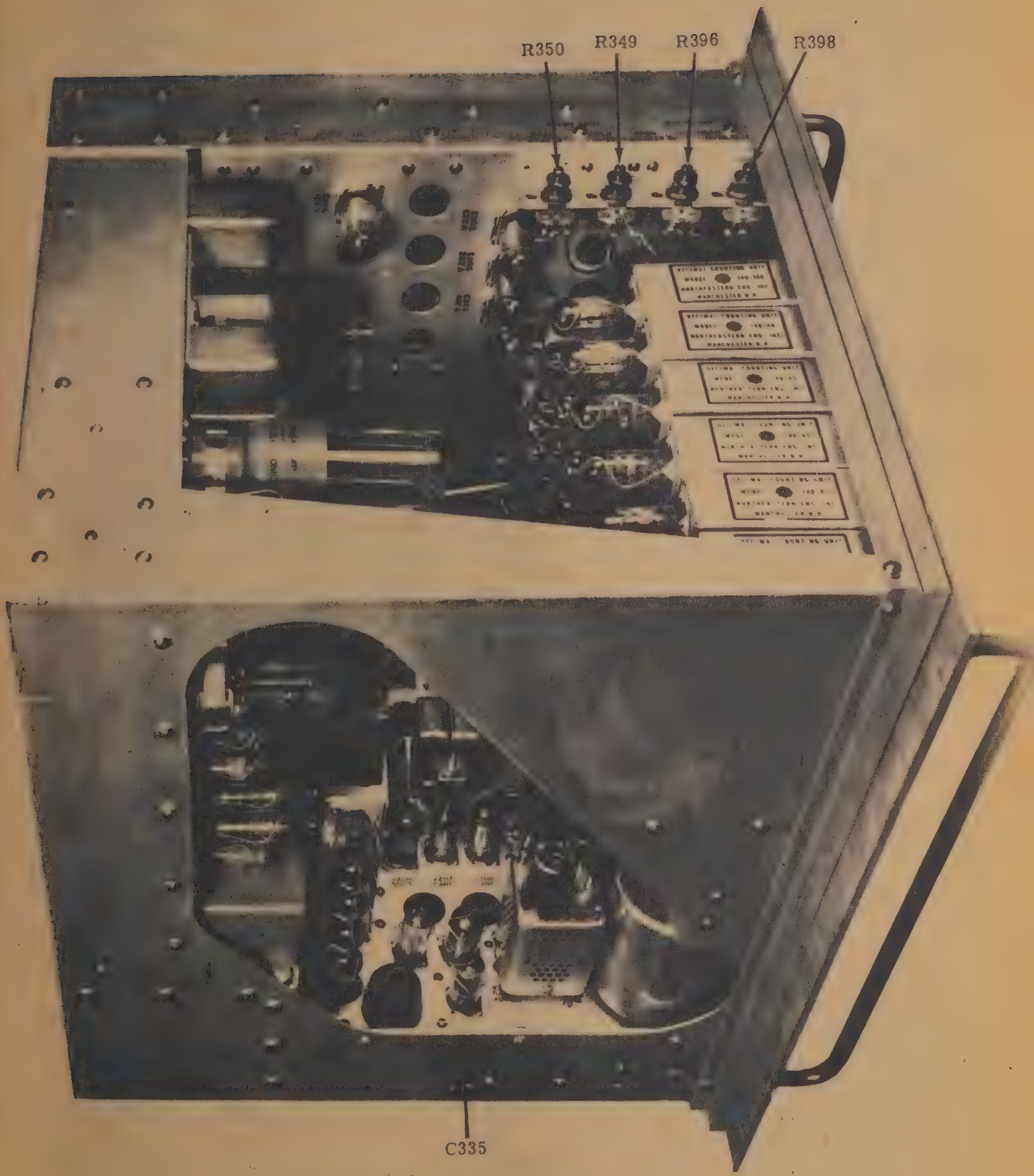


Figure 7. Frequency Counter, Interior.

7. Set MANUAL GATE switch to OPEN. A reading increasing by 100,000 counts each second should be displayed on the counters.

8. Turn R211 fully clockwise. Count should stop due to increased bias cutting off the amplifier.

9. Turn R211 slowly counterclockwise watching the counters. An erratic or slow count (50 Kc) should begin. Keep turning counterclockwise until correct count begins - a counter reading which increases by 100,000 counts every second.

10. Watch the two panel meters. If counters tend to jump occassionally and are not stable, increase counterclockwise setting of R211 very slightly until stable readings of the panel meters occurs.

11. Recheck after 24 hours of continuous service and readjust if necessary.

12. Whenever tubes V1101, V1102 or V1103 are replaced the adjustment procedure, steps 1 through 10 should be followed.

VIII. ADJUSTING PERIOD SENSITIVITY.

The period sensitivity is set by adjusting the bias on one half of tube V701 in the amplitude discriminator, Z202. This is a plug-in unit next to the trigger unit Z201 on the gate rack section. Bias on one half of V701 is controlled by the PERIOD SENS control R248 located near R211 and R224 on the lower edge of the right hand side of the chassis. This control should be adjusted whenever tubes V701 or V702 are replaced in the amplitude discriminator.

1. Remove the unit from the dust cover by loosening the four captive screws at the rear and withdrawing the unit. This allows access to R248.

2. Install a plug-in unit or if one is not available use the special shorting plug.

3. Turn POWER switch on and allow at least five minutes warm-up time.

4. Set FUNCTION SELECTOR switch to PERIOD position.

5. Set TIME UNIT switch to 10 Mc position.

6. Set DISPLAY TIME to minimum position.

7. Throw 100 KC STANDARD switch to INT position.

8. Connect a 1000 cycle signal from an audio oscillator with controlable output voltage to the SIGNAL INPUT connector on the front panel.

9. Adjust the voltage output of audio oscillator to 2 volts rms.

10. Adjust PERIOD SENS control R248 for consistent operation of the counter if necessary.

11. Reduce output voltage from the audio oscillator in small steps readjusting R248 after each step to maintain stable counting operation. It should be possible to obtain stable operation with a voltage output from the audio oscillator as low as 0.3 volts rms.

12. Readjust R248 again after 24 hours of continuous operation.

IX. METER ADJUSTMENT.

The indicating meters M201 and M202 should normally give little trouble, however, controls are provided to adjust the zero reading and the center reading of each meter. These controls are located on a bracket attached to the chassis directly behind the meters and are accessible when the unit is removed from the dust cover. The ZERO controls are variable resistors R253 for the units meters and R257 for the tens meter. The CENTER positioning controls are variable resistors R254 for the units meter and R258 for the tens meter. Adjustments should be made with a line voltage of 115 volts.

A. Setting the Meters

1. With the unit connected to the power source but with power switch off, adjust the pointer on each meter to the dot on the scale between 4 and 5 with the adjustment screw on the face of the meter.

2. Turn power switch ON and allow several minutes warm-up time.

3. Set the panel controls for self-checking:- i.e.

FUNCTION SELECTOR to 100 KC CHECK
FREQUENCY UNIT to 10 SEC, STD GATE TIME
MANUAL GATE to CLOSED
100 KC STD to INT
SIGNAL INPUT with no connection.
DISPLAY TIME completely counterclockwise

4. As counting begins - adjust both CENTER controls R349 and R348 until pointers are centered on the dot between 4 and 5. This adjusts the meters to the electrical center of the binary plate voltage swing.

5. Adjust both ZERO controls R350 and R396 until the pointers stop at zero at the end of each swing.

B. Checking Meter Tracking.

After the above adjustments have been made, meter readings should be checked to see that the meter pointer comes close enough to each scale number to insure correct indication on the meters.

1. Set panel controls as follows:-

FUNCTION SELECTOR to MANUAL GATE
MANUAL GATE to OPEN
TIME UNIT to EXT
100 KC STD to INT

2. Connect a 1 cps signal to STD FREQ OUTPUT connector on front panel. A 1 cps test signal can be obtained from pin 2 of phantastron tube V247 (or yellow lead, ungrounded end of resistor R474) for this purpose.

3. Units meter reading should advance by one count per second and the pointer should come near enough to each digit so as to leave no doubt as to the indicated count. R349 and R350 may be readjusted slightly to improve tracking if necessary.

4. Tens meter reading should advance by one every time unit meter returns from 9 to 0. Meter pointer should come near enough to each digit to insure correct reading of indicated count. R396 and R398 can be readjusted slightly to improve tracking if necessary.

C. Causes for Poor Tracking.

If the above (paragraph A & B) adjustments still do not remedy poor tracking, the trouble may lie in the +70 and +90 volt supply, poor tubes or defective plate clamps in the counter circuit. Defective resistors in the meter circuits or defective plate load resistors causing unbalance in the counter circuit binaries can also upset tracking.

X. DIAL CALIBRATION FOR TIME INTERVAL UNIT No. 14-24 I.

There are two identical trigger units, Z102 in the stop channel and Z103 in the start channel, in the Time Interval Unit. Each had three tubes V601, V602, and V603. Bias adjustment on the grid of one half of V601, which fixes the triggering voltage, is controlled by the combined action of the TRIGGER LEVEL VOLTS controls R110 and R122 and the screwdriver adjustment controls R107 and R119 just to the right of the respective TRIGGERING LEVEL VOLTS controls. R107 and R119 are used to properly adjust the operating point for these controls.

Although the calibration of the TRIGGER LEVEL VOLTS controls are only accurate to approximately 20%, whenever the tubes V601, V602 or V603 are replaced it is advisable to recalibrate. The procedure for this follows:-

1. Install Time Interval unit in place in the front panel of the basic unit.
2. Turn POWER switch on and allow at least five minutes warm-up time.
3. Set FUNCTION SELECTOR switch to PERIOD position.
4. Set TIME switch to 10 Mc position.

On Time Interval Unit

5. Set TIME INTERVAL-PERIOD switch to TIME INTERVAL position.

6. Set SLP-COM switch to COM position.

7. Set both TRIGGER SLOPE switches to same polarity, either + or − .

8. Set both TRIGGER LEVEL multiplier controls to 0.

9. Set both TRIGGER LEVEL multiplier controls to X1.

10. Feed a 1 KC sine wave voltage of approximately 1 volt rms to either the START INPUT or STOP INPUT connectors.

11. Rotate the TRIGGER LEVEL control in the start channel to the positive side of zero to the point where the measurement ceases to recur. Note the reading on the TRIGGER LEVEL control.

12. Repeat for the negative side of zero. If the bias control R119 is set correctly the reading at which the measurement stops recurring should be the same either side of zero. If not, adjust R119 until this condition is reached.

13. Repeat steps 11 and 12 for the stop channel, adjusting R107.

SECTION 2.

ALIGNMENT PROCEDURE

I. GENERAL. This section contains information for more complex adjustment and alignment procedure required when certain tubes are replaced or when faulty operation occurs which cannot be corrected by the adjustments of Section 1.

II. ALIGNMENT OF OSCILLATOR CIRCUIT.

This procedure will be necessary when the oscillator tube V234 is replaced.

A. Peaking the Oscillator.

1. Remove unit from dust cover.

2. Turn POWER switch on.

3. Set 100KC STANDARD switch to INT position. Position of other controls is immaterial.

4. Connect the high impedance probe from an oscilloscope or the ac probe of a vacuum tube voltmeter to the junction of C290 and C291 located on terminal board E254 in the Gate Deck section and adjust the oscilloscope for sufficient display of the 1 KC voltage present at this junction. If the vacuum tube voltmeter is used it should read approximately 1 volt rms.

5. Tune rf coil L211 located in the Time Base section for maximum voltage.

6. Standardize the oscillator, see section I, paragraph III of this chapter. If a primary standard 1 KC frequency is available it can also be used with the oscilloscope to standardize the frequency of the oscillator.

7. If a new V234 oscillator tube is installed standardize again after 24 hours continuous operation.

B. Adjustment Procedures for the ADJ Control.

The ADJ control C294, used in standardizing the oscillator, may reach a position near the limits of its range where it is no longer sufficiently effective in bringing the oscillator to correct frequency. Adjusting the two capacitors C295 and C296 located on a bracket in the Gate Deck section will enable the ADJ control to be brought back to the center region of its range.

1. Remove unit from dust cover. This will allow access to C295 and C296.

2. Set the controls as follows:-

FUNCTION SELECTOR to 100 KC CHK

FREQUENCY UNIT to 0.1 SEC

TIME UNIT to 100 KC

DISPLAY TIME to minimum

100 KC STANDARD to INT

No plug-in unit is necessary.

3. Turn POWER switch on and allow at least 15 minutes warm-up time.

4. Set ADJ control on the front panel at the middle of its range, slot vertical.

5. Standardize the oscillator by either method as outlined in paragraph III of Section 1, of this chapter by adjusting C295 and C296, trying to keep the capacitance equal between them.

6. Recheck the voltage output again (see paragraph A). Retune L211 if necessary.

7. After 24 hours of continuous operation standard the oscillator by the regular procedure using the ADJ control.

III. ALIGNING THE 10 MC MULTIPLIER CIRCUIT.

The Frequency Converter 14-21C is necessary to the procedure of aligning the 10 MC multiplier circuits. This circuit consists of a four stage amplifier which multiplies the 100 KC oscillator output to give a standard frequency output of 10 MC which is used to control the gate circuit with TIME unit switch in 10 MC position. It includes tubes V237, V238, V239, and V240 located in the time base section. The output coupling circuit of V237 is tuned to the fourth harmonic (multiplying 4 times) and the output coupling circuits of V238 and V239 are each tuned to the fifth harmonic (each multiplying 5 times). No multiplication takes place in the final stage of V240. If any of these tubes are replaced the circuit will need retuning.

1. Remove unit from dust cover.

2. With Frequency Converter 14-21C in place turn POWER switch on and allow 15 minutes warm-up time.

3. Set controls on main unit as follows: FUNCTION SELECTOR to FREQUENCY; FREQUENCY UNIT to .1 SEC; TIME UNIT to 10 MC; DISPLAY TIME to minimum; 100 KC STANDARD to INT. Line voltage should be 115v for best accuracy.

4. Set controls on Frequency Converter as follows: MIXING FREQUENCY to 0. Position of other controls immaterial.

5. Clip an alligator type clip on the end of a single wire lead over the insulation on the blue lead to the plate of V237. Connect the other end of this wire to the center conductor of the SIGNAL INPUT connector on the main unit. This should be sufficient to couple the output from V237 to the SIGNAL INPUT circuit.

6. Connect the ac probe of a vacuum tube voltmeter to the same point at the SIGNAL INPUT connector.

7. Carefully adjust L212 for maximum indication on the vacuum tube voltmeter in the range through which the counters read 000400.00. Coil L212 and all the other tuning coils are accessible from the bottom of the time base section chassis. By setting the GAIN control on the Frequency Converter to the point where the indicating eye almost closes, the eye may be used to indicate proper setting of L212. Adjust L212 for maximum closure of the eye.

8. Move the clip from plate lead of V237 to blue wire plate lead of V238. A counter reading of 002000.00 should result.

9. Carefully adjust L213 and L214 for maximum voltage on the voltmeter or maximum closing on the indicator eye in the range through which the counter reading is 002000.00.

10. Move the clip from the plate lead of V238 and connect to the STD FREQ OUTPUT connector on the front panel. A counter reading of 010000.00 should result.

11. Carefully adjust L215, L216, L217, and L218 for maximum voltage on the voltmeter or eye closure on the indicating eye in the range through which the counter reading is 010000.00

IV. ALIGNMENT PROCUREMENT FOR FREQUENCY CONVERTER 14-21C.

The Frequency Converter has two functions, acting as an amplifier with signals of frequency less than 10 MC and converting signals with frequencies between 10 and 100 MC to signals that can be measured by the basic unit. To do this the following circuits are provided: a tuned video amplifier consisting of tubes V1 and V2 operating push-pull, a harmonic generator V5 to provide the necessary mixing signal, a balanced mixer circuit V3 and V4 and a final two-stage video amplifier V6 and V7. A tuning eye indicator V8 is also provided to aid in proper tuning. Adjustments are necessary to align the circuits when any of the tubes V1 to V5 are replaced. When making these adjustments connect the converter to the main unit with the two provided test cables instead of operating with the converter in its accustomed place. These cables provide the needed electrical connections to operate the unit from a position where the necessary circuit adjustments are accessible.

NOTE

When making adjustments in the frequency converter make sure that no wires are displaced from their position. Changes in wire spacing can sufficiently change stray capacitances to upset circuit balance and adjustment.

1. Adjusting Output from Harmonic Generator.

a. Connect the converter to the main unit with the test cables and turn POWER switch on. Allow 15 minutes warm-up time.

b. Set controls on the main unit as follows:- FUNCTION SELECTOR to FREQUECY, FREQUENCY UNIT to .01 SEC, DISPLAY TIME to minimum, 100 KC STANDARD to INT.

c. Set controls on the converter as follows:- TUNING RANGE MC to 10-20, MIXING FREQUENCY to TUNE, GAIN to MAX.

d. Feed a 15 MC CW signal with a voltage level of 20 millivolts from an external signal generator to the SIGNAL INPUT connector of the main unit. The input impedance is approximately 50 ohms at this frequency.

e. Adjust TUNING dial on converter for maximum deflection of tuning eye.

f. Set MIXING FREQUENCY switch on converter to 10 position.

g. Adjust C32 and then C49 with a low capacity aligning tool for maximum deflection of the tuning eye. If eye closes completely reduce voltage output from signal generator so that a clear indication may be obtained. Repeat this several times as the settings of these two capacitors are interdependent.

h. Repeat the above procedure for each of the following input frequencies and control settings.

Signal Generator Frequency MC	Tuning Range MC	Mixing Frequency	Adjust
25	20-40	20	C34, C51
35	20-40	30	C36, C53
45	40-100	40	C38, C55
55	40-100	50	C30, C47
65	40-100	60	C28, C45
75	40-100	70	C26, C43
85	40-100	80	C25, C42
95	40-100	90	C24, C41

The counter reading in each of the above cases should be 0005000.0 if the signal generator frequency is accurate. Slight increase in signal generator frequency should result in corresponding increase in counter reading

2. Adjusting Balanced Mixer Circuit.

Two interrelated adjustments are necessary, one for the drive and one for the balance.

a. Connect converter as in paragraph 1. a.

b. Set main unit controls the same as paragraph 1. b. except 100 KC STANDARD to EXT. Remove any connection from 100 KC INPUT.

c. Set converter controls the same as paragraph 1. c.

d. With signal generator connected as in paragraph 1. d. adjust frequency output to 10.1 MC at 20 millivolts.

e. Adjust TUNING control on converter for maximum deflection of tuning eye.

f. Connect the ac probe of a vacuum tube voltmeter to pin 7 of the socket for the trigger unit Z201 in the main unit located in the gate deck section.

g. Set MIXING FREQUENCY control on the converter to 20.

h. Adjust C17 for minimum voltage on the vacuum tube voltmeter. This should be considerably less than 0.1 volt. If this is not possible check balance of the balanced mixer as follows:-

(1) Set 100KC STANDARD back to INT on main unit.

(2) Set TUNING control to 90 and MIXING FREQUENCY to 10 on converter.

(3) Disconnect signal generator from SIGNAL INPUT connector.

(4) Adjust R15 for minimum reading on the vacuum tube voltmeter. A reading considerably less than 0.1 volt should be obtained.

i. Return controls to original settings, reconnect the signal generator and readjust C17 for minimum voltage, Since the settings of C17 and R15 are interdependent it will be necessary to repeat steps h. and i. several times to ensure correct adjustment.

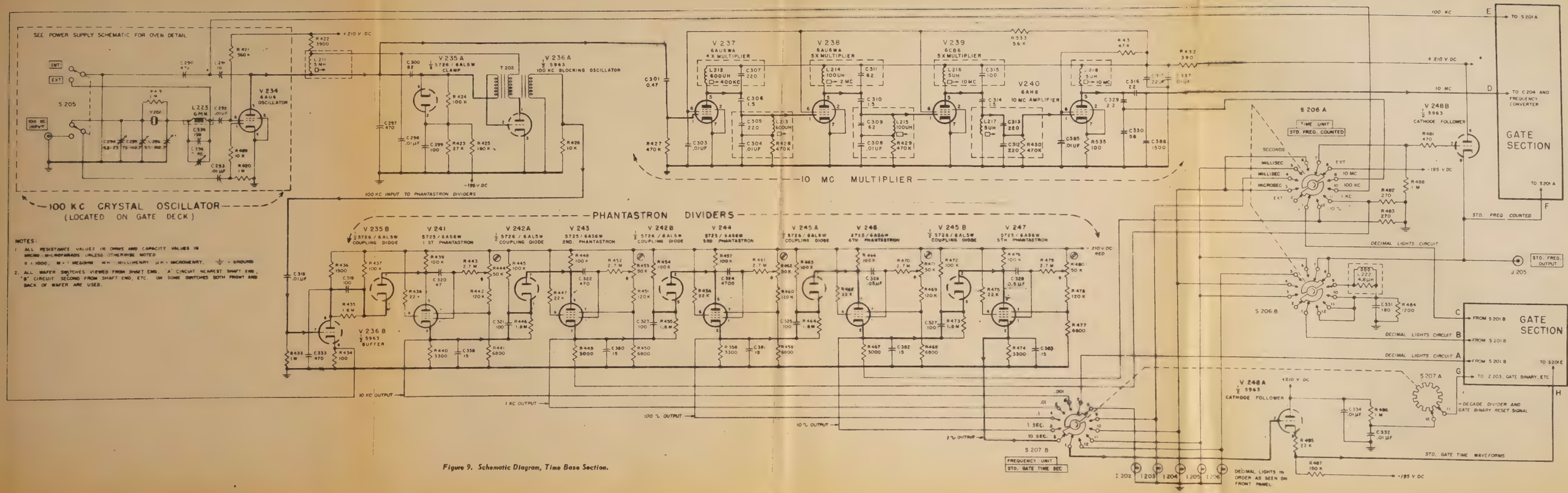
3. Adjusting 10 MC Standard Frequency Input.

This adjustment is made with the converter in proper position in the main unit (do not use test cables).

a. Turn POWER switch on and warm-up thoroughly.

b. Perform steps b. through f. paragraph 1.

c. Adjust L218 located on the bottom of the time base section chassis for maximum deflection of the tuning eye. If eye overlaps, reduce gain on signal generator until a clear indication is obtained on the eye.


SEE POWER SUPPLY SCHEMATIC FOR OVEN DETAIL
INT
EXT
S 205
100 KC INPUT
V 234 6AU6 OSCILLATOR
+210 V DC
V 235 A 1/2 5726 / 6AL5W CLAMP
V 236 A 1/2 5963 100 KC BLOCKING OSCILLATOR
T 203
100 KC INPUT TO PHANTASTRON DIVIDERS
-195 V DC
100 KC CRYSTAL OSCILLATOR
(LOCATED ON GATE DECK)
V 237 6AU6WA 4X MULTIPLIER
V 238 6AU6WA 5X MULTIPLIER
V 239 6CB6 5X MULTIPLIER
V 240 6AH6 10 MC AMPLIFIER
10 MC MULTIPLIER
PHANTASTRON DIVIDERS
V 235 B 1/2 5726 / 6AL5W COUPLING DIODE
V 241 5725 / 6A5EW 1 ST PHANTASTRON
V 242 A 1/2 5726 / 6AL5W COUPLING DIODE
V 243 5725 / 6A5EW 2ND PHANTASTRON
V 242 B 1/2 5726 / 6AL5W COUPLING DIODE
V 244 5725 / 6A5EW 5TH PHANTASTRON
V 245 A 1/2 5726 / 6AL5W COUPLING DIODE
V 246 5725 / 6A5EW 6TH PHANTASTRON
V 245 B 1/2 5726 / 6AL5W COUPLING DIODE
V 247 5725 / 6A5EW 5TH PHANTASTRON
+210 V DC REG
V 236 B 1/2 5963 BUFFER
10 KC OUTPUT
1 KC OUTPUT
100 ~ OUTPUT
10 ~ OUTPUT
1 ~ OUTPUT
S 207 B
FREQUENCY UNIT
STD. GATE TIME SEC.
1 SEC.
10 SEC.
I 202
I 203
I 204
I 205
I 206
DECIMAL LIGHTS IN ORDER AS SEEN ON FRONT PANEL
100 KC
10 MC
TO S 201 A
TO C 204 AND FREQUENCY CONVERTER
GATE SECTION
S 206 A
TIME UNIT
STD. FREQ. COUNTED
SECONDS
MILLISEC
MILLISEC
MICROSEC
V 248 B 1/2 5963 CATHODE FOLLOWER
-195 V DC
STD. FREQ. COUNTED
STD. FREQ. OUTPUT
J 205
DECIMAL LIGHTS CIRCUIT
S 206 B
DECIMAL LIGHTS CIRCUIT
DECIMAL LIGHTS CIRCUIT
FROM S 201 B
FROM S 201 B
FROM S 201 B
TO S 201 E
TO Z 203 GATE BINARY, ETC
V 248 A 1/2 5963 CATHODE FOLLOWER
S 207 A
DECADE DIVIDER AND GATE BINARY RESET SIGNAL
STD. GATE TIME WAVEFORMS

NOTES:

1. ALL RESISTANCE VALUES IN OHMS AND CAPACITY VALUES IN MMFD - MICROFARADS UNLESS OTHERWISE NOTED
   K = 1000, M = 1 MEGOHM MH = MILLIHENRY UH = MICROHENRY, ⏚ = GROUND
2. ALL WAFER SWITCHES VIEWED FROM SHAFT END, 'A' CIRCUIT NEAREST SHAFT END, 'B' CIRCUIT SECOND FROM SHAFT END, ETC. ON SOME SWITCHES BOTH FRONT AND BACK OF WAFER ARE USED.

Figure 9. Schematic Diagram, Time Base Section.

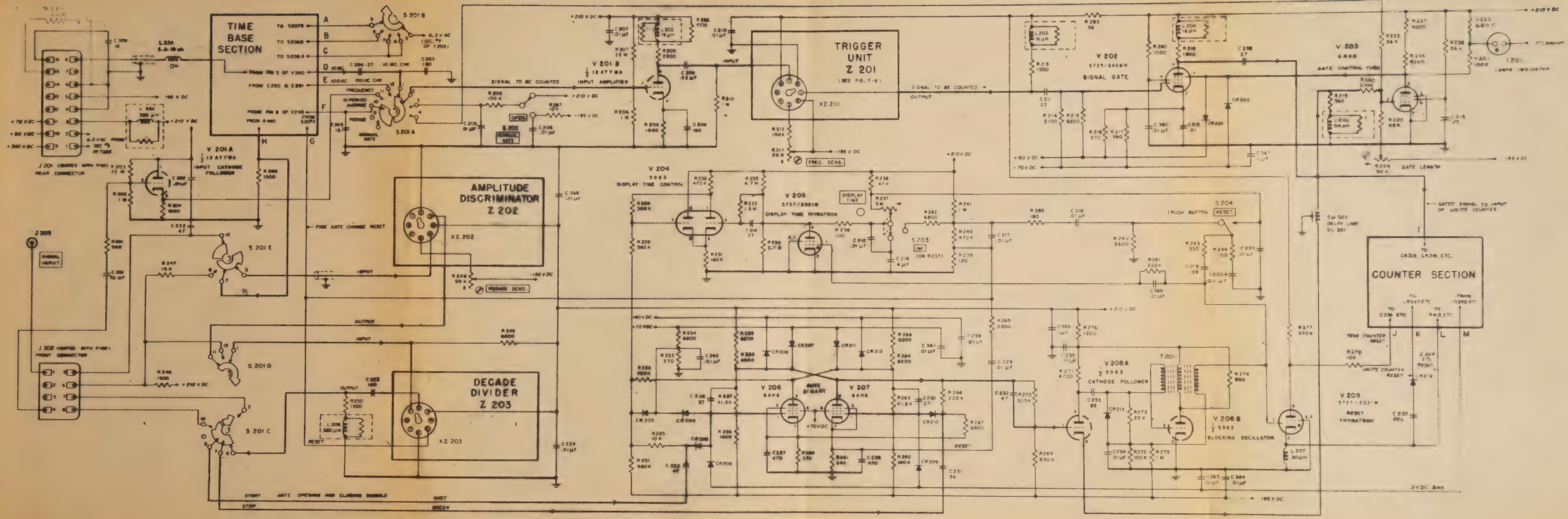


Figure 10. Schematic Diagram, Gating Section.

REVISIONS			
SYM.	DESCRIPTION	DATE	APPROVAL

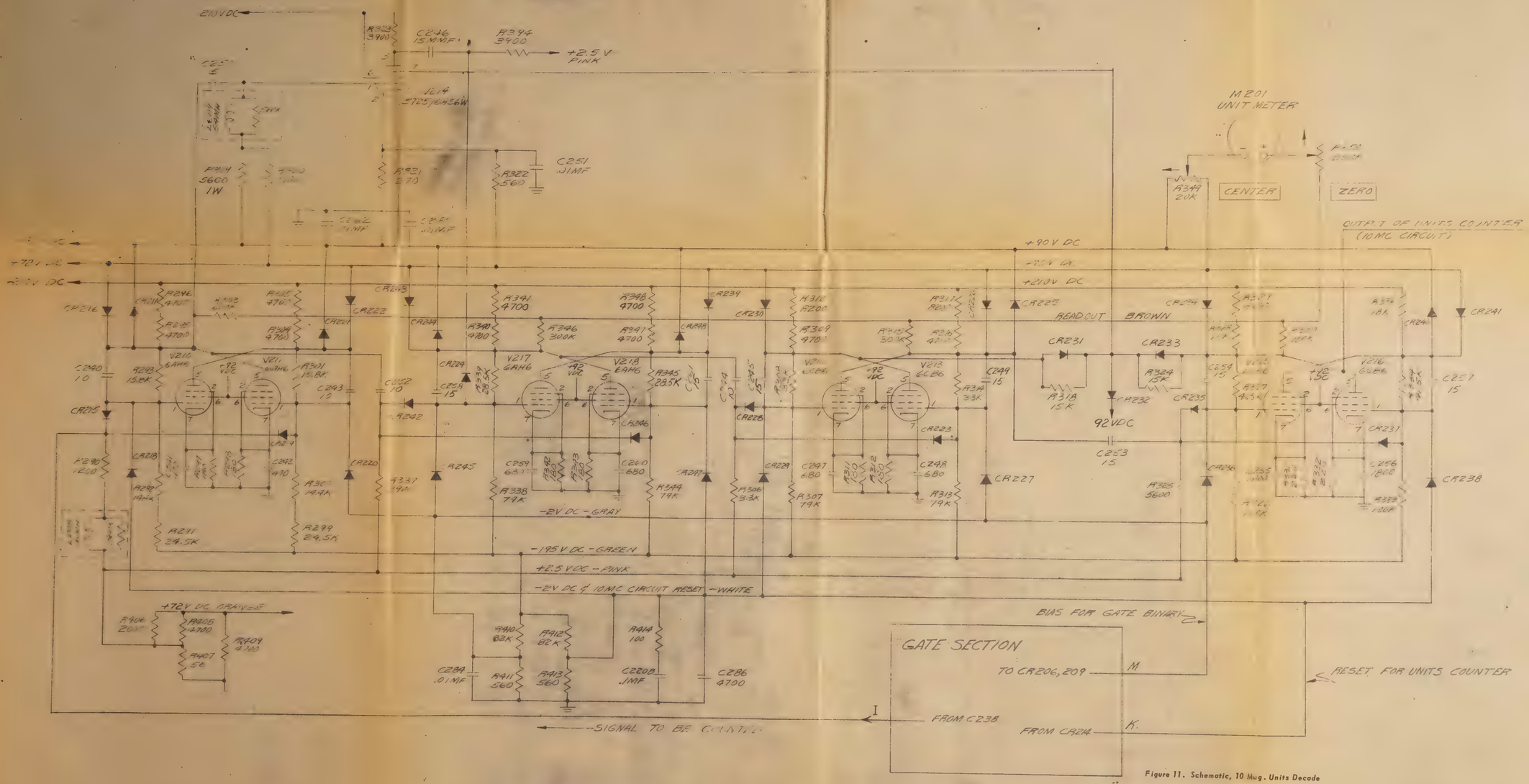


Figure 11. Schematic, 10 Mug. Units Decade

D100187

TENS COUNTER SECTION
(1 MC CIRCUIT)

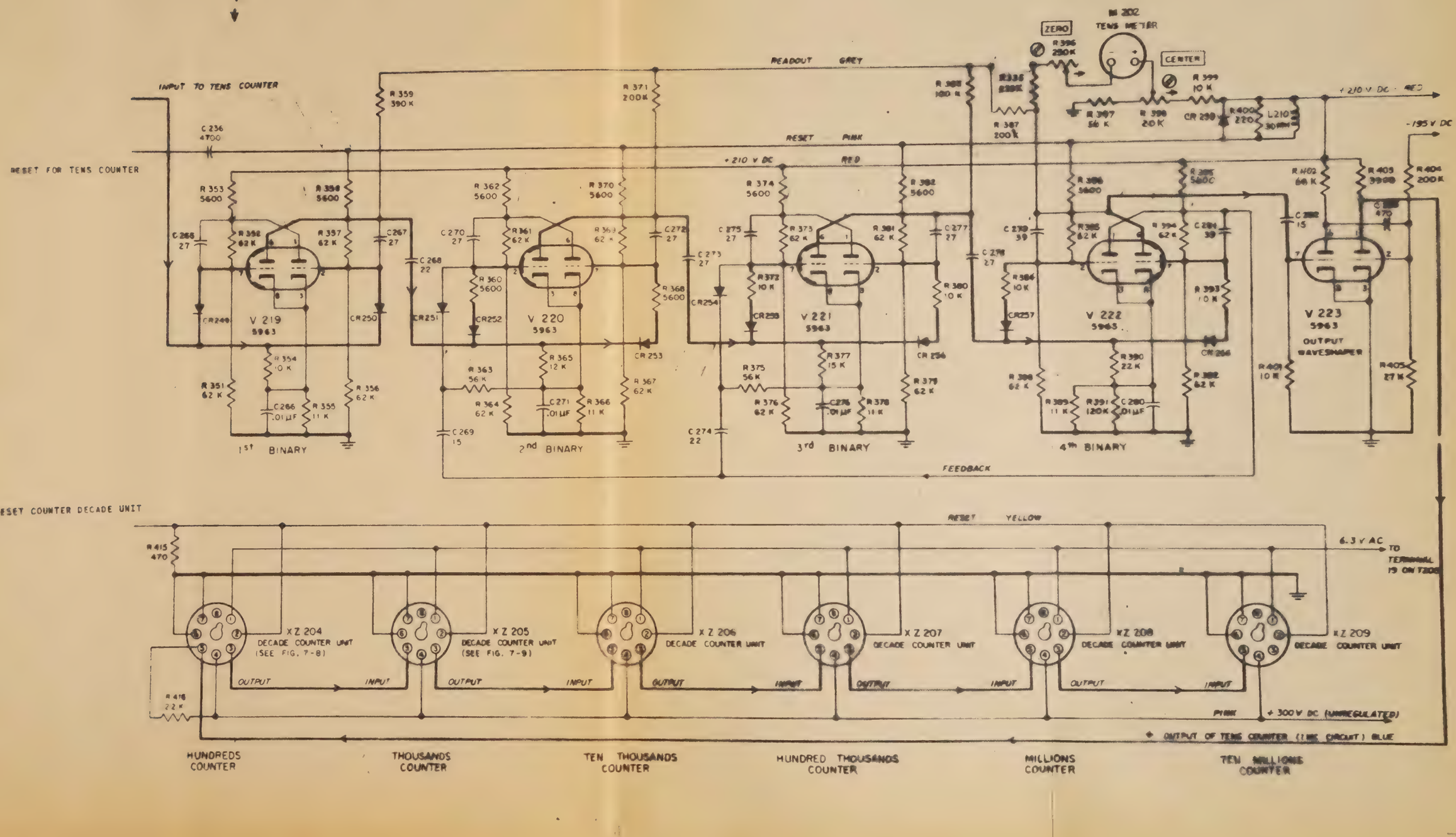


Figure 12. Schematic Diagram, Tens Counter Section.

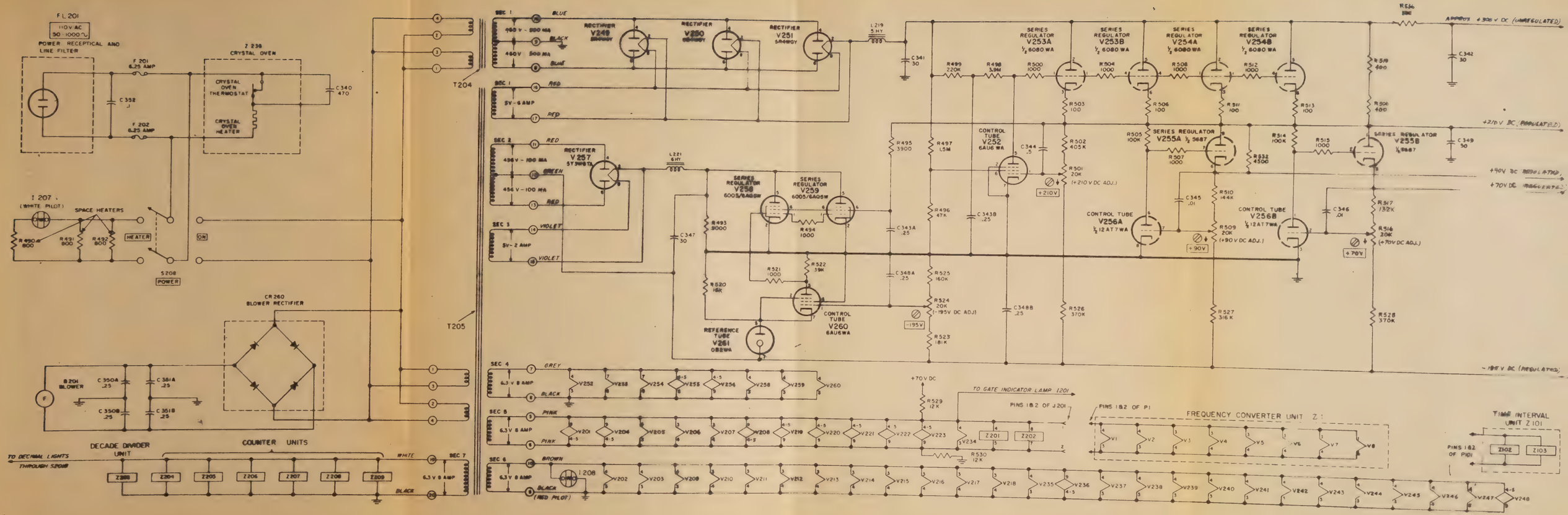


Figure 13. Schematic Diagram, Power Supply.

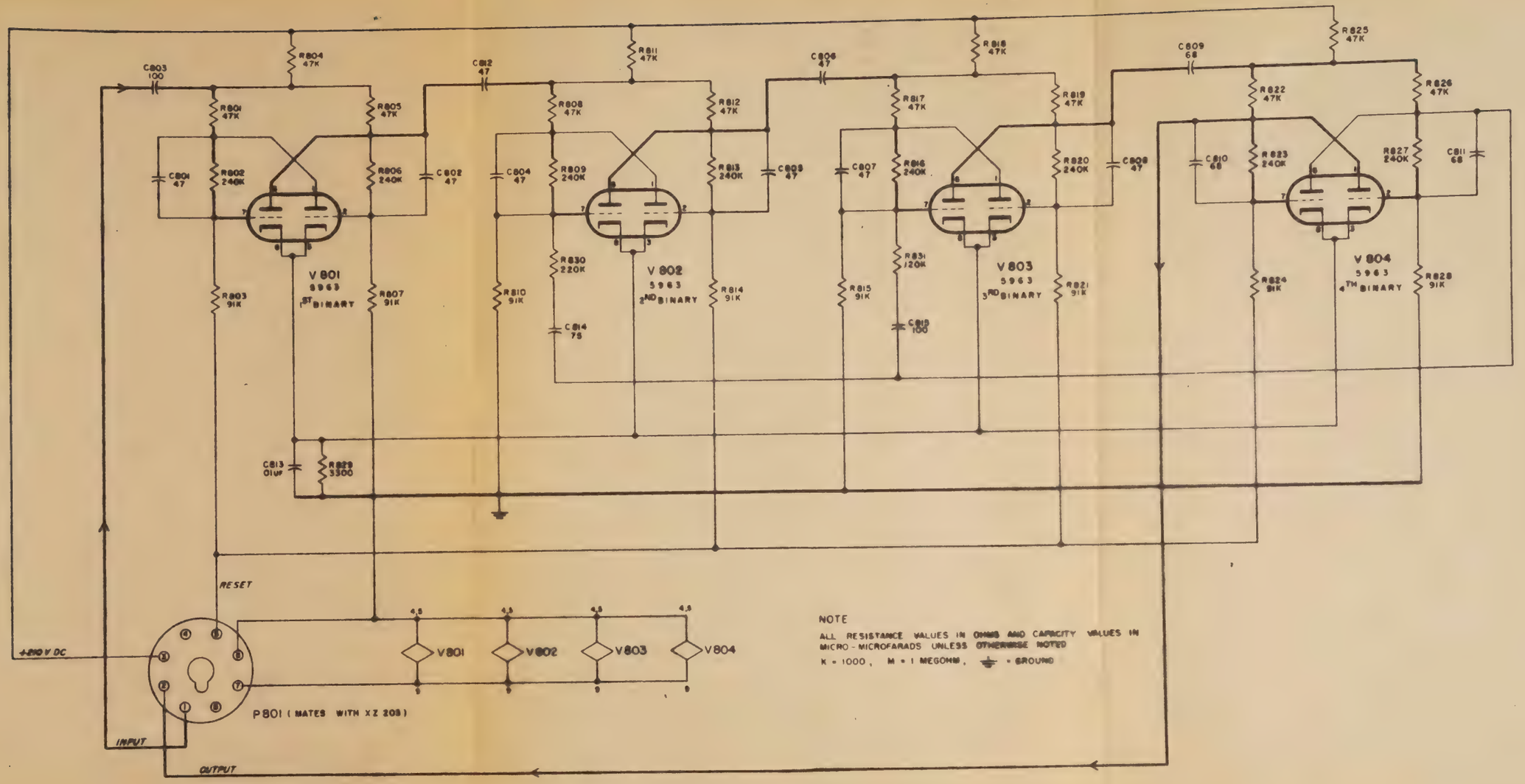


Figure 14. Schematic Diagram, Decade Divider

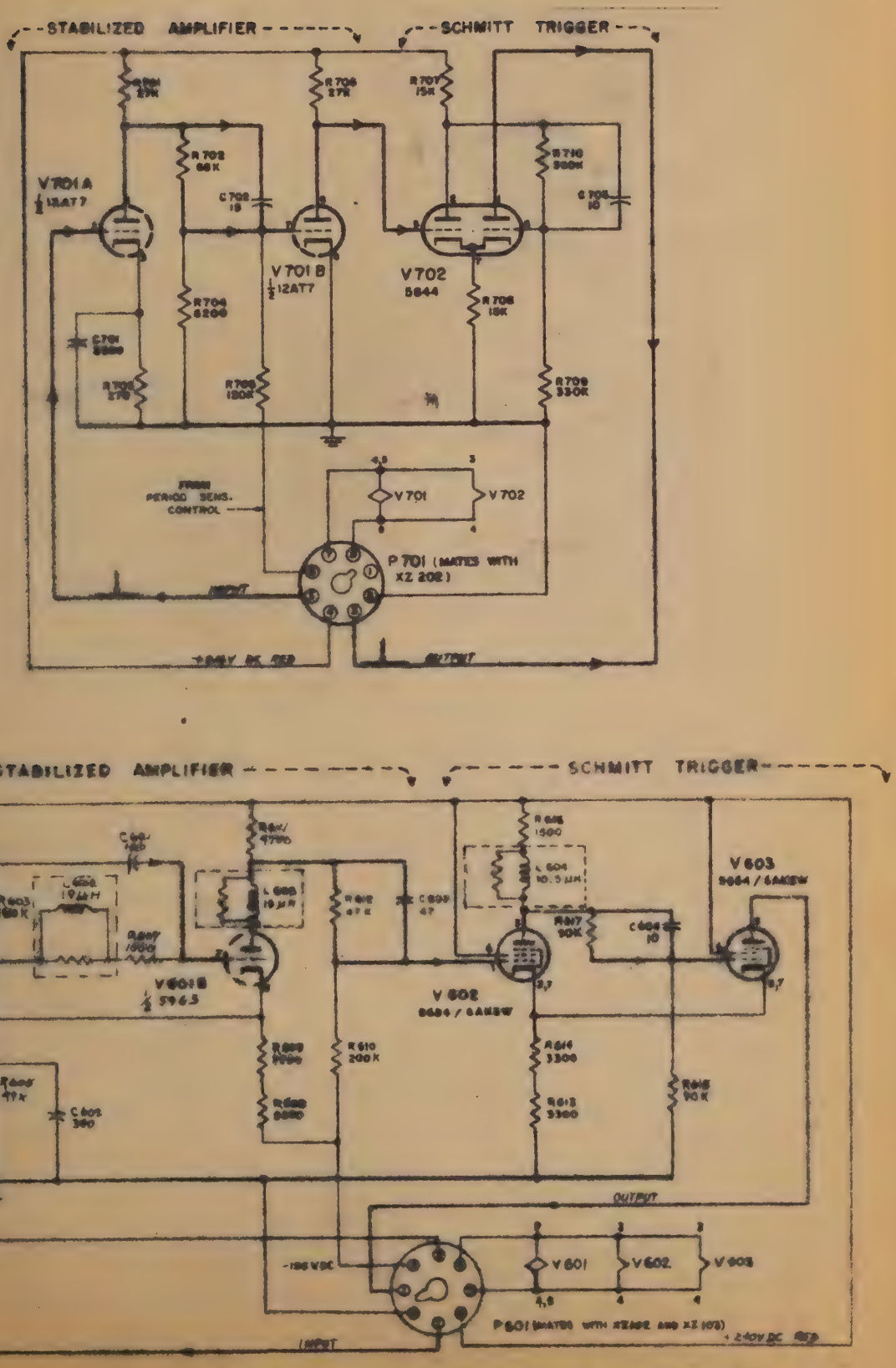


Figure 15. Schematic Diagram, Amplitude Discriminator (top) and Time Interval Trigger (bottom).

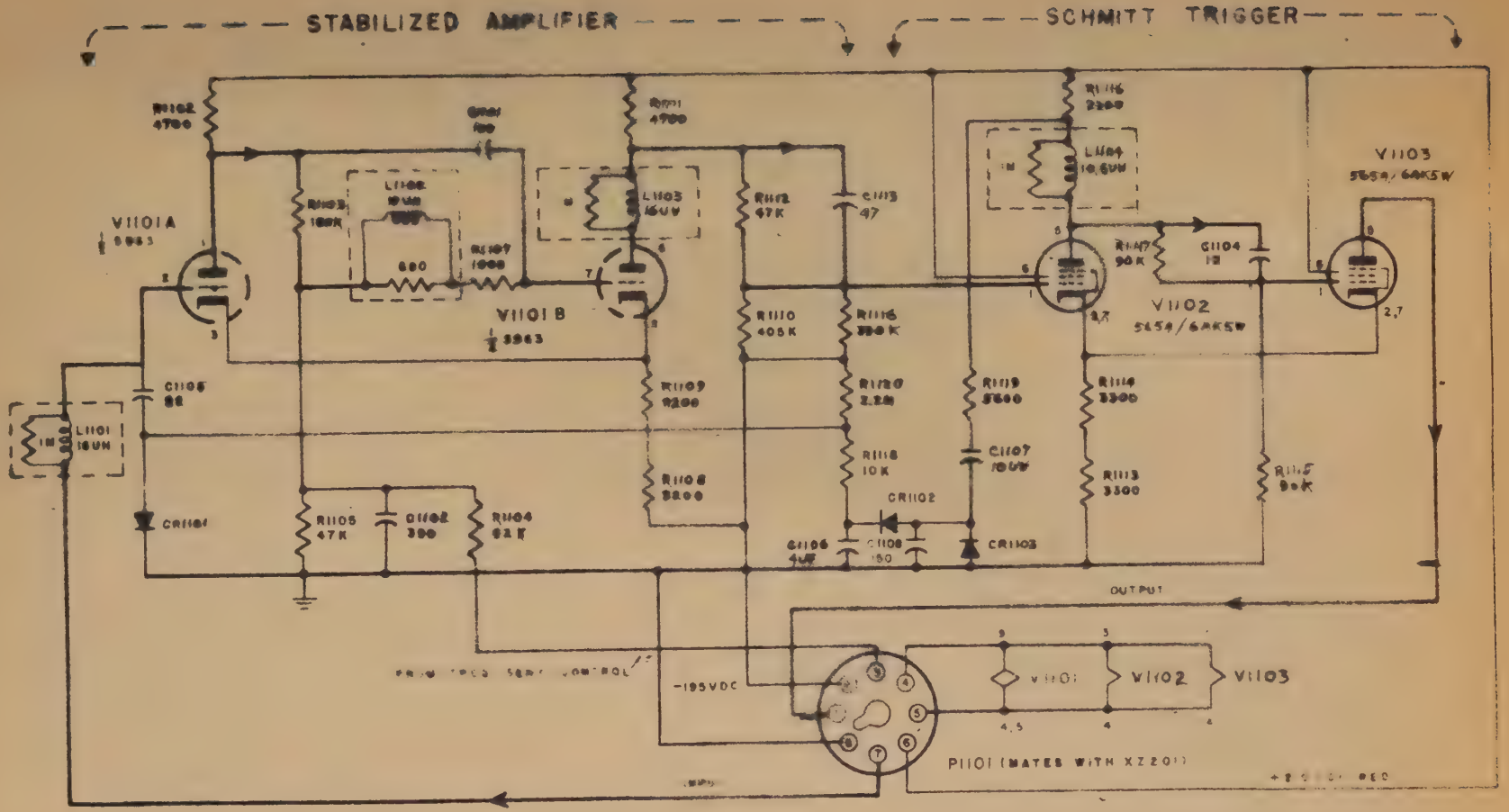


Figure 16. Schematic Diagram, Frequency Counter, Trigger.

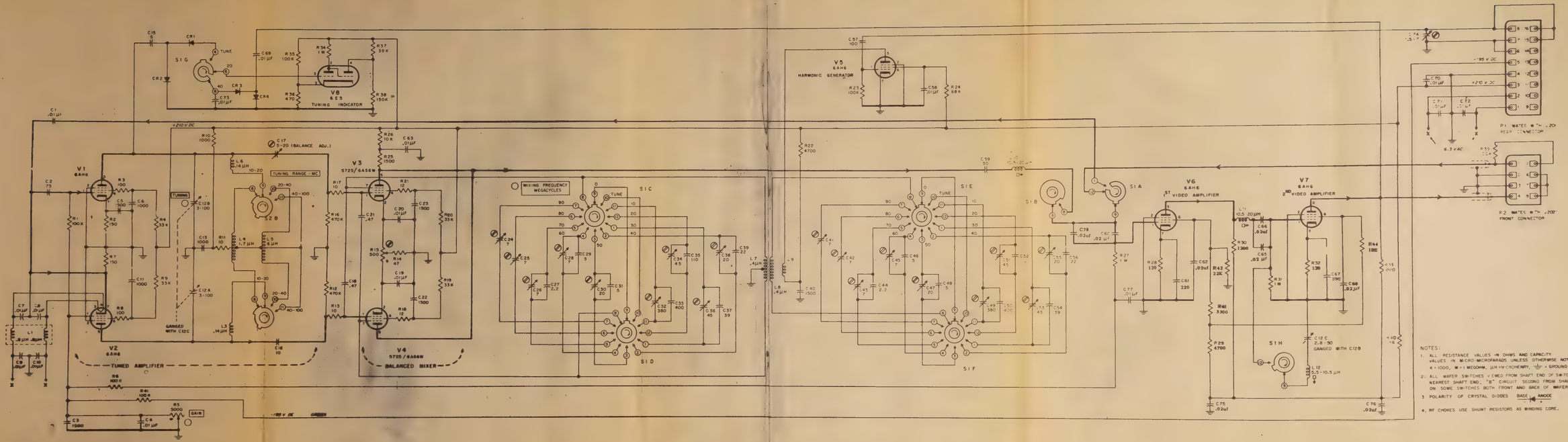


Figure 17. Schematic Diagram, Frequency Converter

NOTES:

1. ALL RESISTANCE VALUES IN OHMS AND CAPACITY VALUES IN MICRO-MICROFARADS UNLESS OTHERWISE NOTED. K = 1000, M = 1 MEGOHM, μH = MICROHENRY, ⏚ = GROUND.
2. ALL WAFER SWITCHES VIEWED FROM SHAFT END OF SWITCH. "A" CIRCUIT NEAREST SHAFT END, "B" CIRCUIT SECOND FROM SHAFT END, ETC. ON SOME SWITCHES BOTH FRONT AND BACK OF WAFER ARE USED.
3. POLARITY OF CRYSTAL DIODES BASE ——▶| ANODE
4. RF CHOKES USE SHUNT RESISTORS AS WINDING CORE.

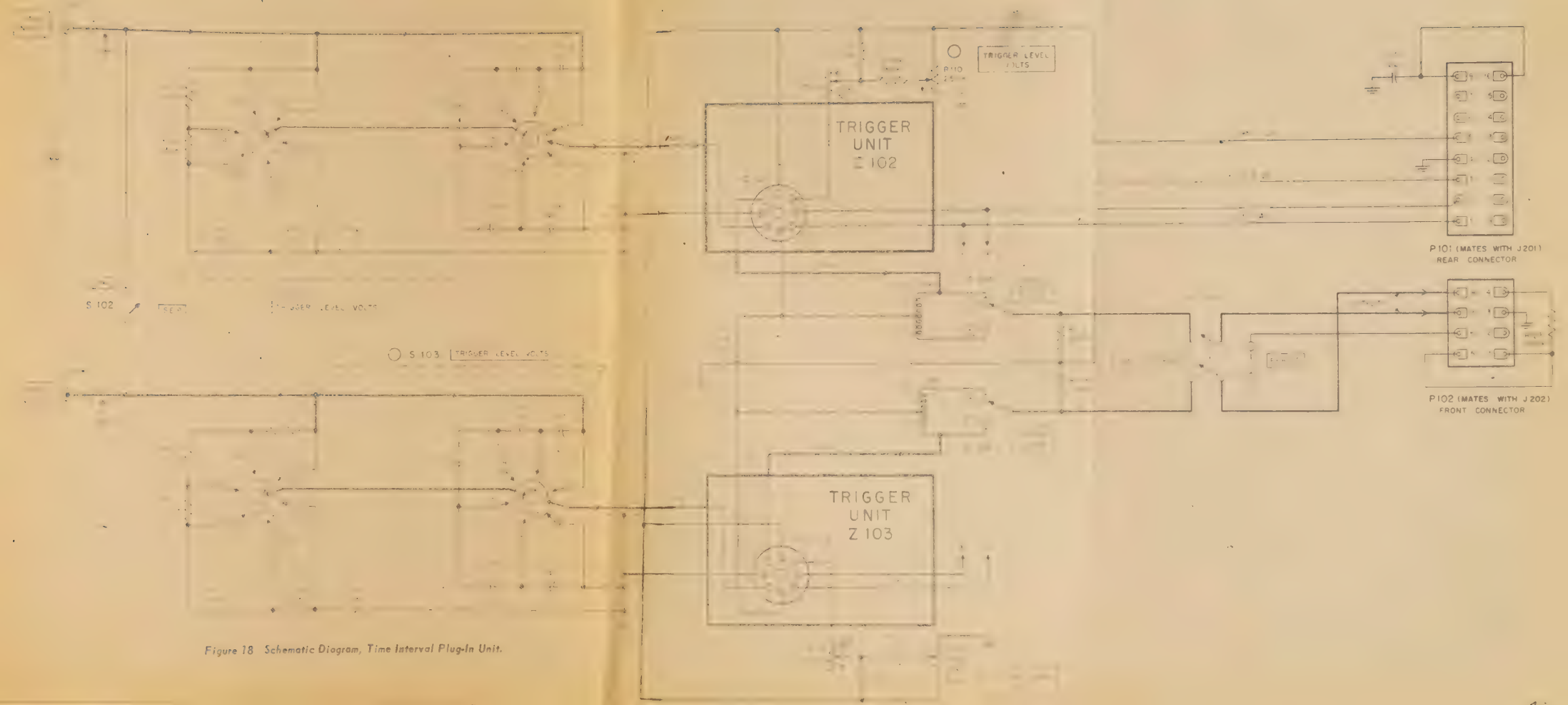


Figure 18 Schematic Diagram, Time Interval Plug-In Unit.

PARTS LIST

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	PART NO.
C1, C4, C5, C7 to C10, C19, C20, C58, C63, C70 C71, C72, C73, C77, C108 C202, C205, C206, C207, C210, C212, C215, C217, C218, C221, C224, C229, C234, C235, C239, C251, C262, C266, C271, C276, C280, C284, C285, C292, C293, C298, C303, C304, C308, C318, C332, C334, C337, C345, C346, C360 to C365, C368, C385, C813	CAPACITOR, fixed, ceramic .01 mf, +100 −20% 500V	CK63Y103Z
C2, C814	CAPACITOR, fixed, ceramic 75 mmf, ±5%, 500V	CC26TH750J
C3, C22, C23, C40, C386	CAPACITOR, fixed, ceramic 1500 mmf ±20%, 500V Erie Resistor Corp.	326−1500
C6, C11, C13	CAPACITOR, fixed, ceramic 1000 mmf, ±20%, 500V Erie Resistor Corp	327−1000
C15	CAPACITOR, fixed, ceramic 5 mmf within .5 mmf., 500V	CC21CH050D
C16, C604, C1104	CAPACITOR, fixed ceramic 10 mmf within .5 mmf, 500V	CC21CH100D
C60, C62, C65, C66, C68 C75, C76, C78	CAPACITOR, fixed, ceramic 20,000 mmf, 600V Centralab	DD−203
C801, C802, C804, C805, C806, C807, C808, C812	CAPACITOR, fixed, ceramic 47 mmf, ±5%, 500V	CC30CH470J
C815	CAPACITOR, fixed, ceramic 100 mmf, ±5%, 500V	CC26UJ101J
C341, C342, C347	CAPACITOR, fixed, electrolytic 30 mf, 450V	CE41E300R
C349	CAPACITOR, fixed, electrolytic 50 mf, 300V	CE41E500N
C1106	CAPACITOR, fixed, electrolytic 4mf, 6V Sprague Mfg Co.	101D, 4mf, 6V
C1107	CAPACITOR, fixed, electrolytic 10mf, 300V	CE31C100N
C18, C21, C301	CAPACITOR, fixed, oxide, dielectric 0.47 mmf, ±5%, 500V Stackpole Carbon Co.	GAO .47 mmf
C27, C44, C329	CAPACITOR, fixed, oxide, dielectric 2.2 mmf, ±10%, 500V Stackpole Carbon Co.	GA-4 2.2 mmf
C306, C310, C314	CAPACITOR, fixed, oxide, dielectric 1.5 mmf ±20%, 500V Stackpole Carbon Co.	GA-3 1.5 mmf
C29, C31, C46, C48, C347	CAPACITOR, fixed, mica 5 mmf, ±20%, 300V	CM15B050M
C33, C50	CAPACITOR, fixed, mica 390 mmf, ±5%, 300V	CM15D391J
C35, C52	CAPACITOR, fixed, mica 110 mmf, ±5%, 300V	CM15C111J
C37, C54	CAPACITOR, fixed, mica 39 mmf, ±5%, 300V	CM15C390J
C39, C56, C107, C316	CAPACITOR, fixed, mica 22 mmf, ±5%, 300V	CM15C220J
C57, C208, C223, C299 C319, C321, C323, C325 C327, C601, C1101	CAPACITOR, fixed, mica 100 mmf, ±10%, 500V	CM20B101K

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	PART NO.
C59, C105, C112, C222 C225, C232, C320, C603, C1103	CAPACITOR, fixed, mica 47 mmf, ±10%, 500V	CM20B470K
C61	CAPACITOR, fixed, mica 220 mmf, ±10%, 500V	CM20B221K
C67, C602, C1102	CAPACITOR, fixed, mica 390 mmf, ±10%, 500V	CM20B391K
C101, C114, C240, C243, C245, C249, C291, C703 C258, C261	CAPACITOR, fixed, mica 10 mmf, ±10%, 500V	CM20B100K
C102, C104, C109, C113, C244, C246, C252, C253, C254, C257, C269, C282, C338, C369, C370, C380, C381, C382, C383, C702	CAPACITOR, fixed, mica 15 mmf, ±10%, 500V	CM20B150K
C103, C110, C204, C213 C214, C226, C230, C238, C265, C267, C270, C272, C273, C275, C277, C278,	CAPACITOR, fixed, mica 27 mmf, ±10%, 500V	CM20B270K
C106, C111, C233, C300 C1105	CAPACITOR, fixed, mica 82 mmf, ±10%, 500V	CM20B820K
C219, C264, C279, C281	CAPACITOR, fixed, mica 39 mmf, ±10%, 500V	CM20B390K
C227, C228, C241, C283, C290, C297, C322, C333, C340	CAPACITOR, fixed, mica 470 mmf, ±10%, 500V	CM20B471K
C231, C330	CAPACITOR, fixed, mica 56 mmf, ±10%, 500V	CM10B560K
C236	CAPACITOR, fixed, mica 4700 mmf, ±10%, 500V	CM35B472K
C237	CAPACITOR, fixed, mica 560 mmf, ±10%, 500V	CM30B561K
C247, C248	CAPACITOR, fixed, mica 680 mmf, ±10%, 500V	CM30B681K
C250	CAPACITOR, fixed, mica 5 mmf, ±20%, 500V	CM20B050M
C255, C256	CAPACITOR, fixed, mica 1800 mmf, ±10%, 500V	CM30B182K
C259, C260	CAPACITOR, same as C247	
C268, C274, C211	CAPACITOR, fixed, mica 22 mmf, ±10%, 500V	CM20B220K
C286	CAPACITOR, fixed, mica 4700 mmf, ±10%, 500V	CM20B472K
C305, C307, C312, C313	CAPACITOR, fixed, mica 220 mmf, ±5%, 300V	CM15D221J
C309, C311	CAPACITOR, fixed, mica 62 mmf, ±5%, 500V	CM20C620J
C315	CAPACITOR, fixed, mica 100 mmf, ±10%, 300V	CM15B101K
C324	CAPACITOR, fixed, mica 4700 mmf, ±10%, 500V	CM30B472K
C331, C803	CAPACITOR, fixed, mica 180 mmf, ±10%, 500V	CM20B181K
C336	CAPACITOR, fixed, mica 150 mmf, ±5%, 500V	CM25D151J
C701	CAPACITOR, fixed, mica 3300, ±10%, 500V	CM30B332K
C809, C810, C811	CAPACITOR, fixed, mica 68 mmf, ±5%, 300V	CM15C680J
C1108	CAPACITOR, fixed, mica 150 mmf, ±10%, 500V	CM20B151K

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	PART NO.
C69	CAPACITOR, fixed, paper 10,000 ohms, ±20%, 1 section, 600V	CP25A1EF103M
C201, C352	CAPACITOR, fixed, paper 100,000 ohms ±20%, 1 section, 600V	CP26A1EF104M
C209, C317	CAPACITOR, fixed, paper, dielectric 200,000 mmf, ±20%, 400V 1 section -Northeastern Engineering, Inc.	A17869
C216	CAPACITOR, fixed, paper 4 meg, ±10%, 1 section, 600V	CP41B1FF405K
C220AB	CAPACITOR, fixed, paper 100,000 ohms, +10-20%, 2 sections, 1000V	CP54B4FG104V
C326	CAPACITOR, fixed, paper 50,000 ohms, ±10%, 1 section, 600V	CP54B1FF503K
C328, C344AB	CAPACITOR, fixed, paper 500,000 ohms, ±10%, 1 section, 600V	CP54B1FF504K
C343AB, C348AB, C350AB, C351	CAPACITOR, fixed, paper 250,000 ohms, +20-10%, 2 sections, 600V	CP54B6EF254V
C366, C367	CAPACITOR, fixed, paper 1 meg, ±10%, 1 section, 600V	CP61B1FF105K
C12	CAPACITOR, variable, air dielectric, 3 sections; 100 mmf max, 4 mmf min. 2 sections, other section 48 mmf max, 1.5 mmf min. -Northeastern Engineering, Inc.	B-17188
C32, C49	CAPACITOR, variable, air dielectric (trimmer), 380 mmf max, 50 mmf min. -Avco Electronics, Inc.	465 (Elmerco)
C294	CAPACITOR, variable, air (trimmer) 4 mmf - 23 mmf, slotted shaft	CT1C025
C295, C296	CAPACITOR, variable, air (trimmer) 7.5 mmf-99 mmf	CT1C100
C17, C55, C47, C38, C30	CAPACITOR, variable, ceramic 5 mmf - 20 mmf	CV11B200
C24, C25, C26, C28, C41, C42, C43, C45	CAPACITOR, variable, ceramic 1.5 mmf - 7 mmf	CV11A070
C34, C36, C51, C53, C74, C335	CAPACITOR, variable, ceramic 7mmf - 45 mmf	CV11C450
O101	CASE, TRANSIT -for time interval unit Northeastern Engineering, Inc.	D-17723
O201	CASE, TRANSIT -for Frequency Meter and Accessories Northeastern Engineering, Inc.	A-17856
Z8	COIL ASSEMBLY, Radio Frequency -three coils L7, L8, L9 Northeastern Engineering, Inc.	A-17757
L1	COIL, RF single layer, 22½ turns Northeastern Engineering, Inc.	A-17496
L3, L6	COIL, RF single layer, 5 turns Northeastern Engineering, Inc.	A-17191
L4	COIL, RF single layer, 22 turns Northeastern Engineering, Inc.	B-17192-2
L5	COIL, RF single layer, 10 turns Northeastern Engineering, Inc.	B-17192-1
L10, L11	COIL, RF single layer, 50 turns Northeastern Engineering, Inc.	A-17189
L12, L218, L224	COIL, RF single layer, 32 turns Northeastern Engineering, Inc.	A-17190
L101, L102	COIL, RF single layer, 24 turns Northeastern Engineering, Inc.	A-17209

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	PART NO.
L201	COIL, RF 320 microhenries N. E. Engineering, Inc.	A-17773-8
L202, L602, L1102	COIL, RF 19 microhenries -Northeastern Engineering, Inc.	A-17773-2
L203,L204,L208,L603,L1101	COIL, RF 16 microhenries -Northeastern Engineering, Inc.	A-17777
L205, L209	COIL, RF 54 microhenries - Northeastern Engineering, Inc.	A-17773-7
L206	COIL, RF 320 microhenries -Northeastern Engineering, Inc.	A-17773-4
L207, L210	COIL, RF three layers, 210 turns -N.E. Engineering, Inc.	A-17720
L211	COIL, RF universal wound -Northeastern Engineering, Inc.	A-17497-2
L212, L213	COIL, RF universal wound -Northeastern Engineering, Inc.	A-17497-4
L214, L215	COIL,RF universal wound -Northeastern Engineering, Inc.	A-17497-1
L216, L217	COIL, RF layer wound, 17 turns N.E. Engineering, Inc.	A-17497-3
L222	COIL, RF 4.8 microhenries -Northeastern Engineering, Inc.	A-17774-6
L223	COIL, RF universal wound -Northeastern Engineering, Inc.	A-17792
L601 (2 used)	COIL, RF 25 microhenries -Northeastern Engineering, Inc.	A-17773-1
L604 (2 used), L1104	COIL, RF 105 microhenries -Northeastern Engineering, Inc.	A-17774-3
L1103	COIL, RF 25 microhenries -Northeastern Engineering, Inc.	A-17806
F201 thru F204	FUSE, Cartridge 6¼ amp, slo-blow Bussman Mfg. Co.	MDF 6¼
I201	LAMP, Glow Bayonet base General Electric Co.	NE-51
I202 thru I204	LAMP, Incandescent min. bay. base -General Electric Co.	No. 47
M201, M202	METER, ammeter -Northeastern Engineering, Inc.	B17390
B201A	MOTOR, D.C. 1/60 H.P. -Northeastern Engineering, Inc.	A17560
L219	REACTOR 4.0 henries -Northeastern Engineering, Inc.	C-17402
L221	REACTOR 6.0 henries -Northeastern Engineering, Inc.	B-17396
CR260	RECTIFIER, metallic -Northeastern Engineering, Inc.	B-17498
R1, R6, R23, R39, R108, R120, R123, R205, R424	RESISTOR, fixed, composition 1/2 watt, 100,000 ohms ±10%	RC20GF104K
R2, R7	RESISTOR, fixed, composition 1/2 watt, 150 ohms, ±10%	RC20GF151K
R3, R8, R434, R535	RESISTOR, fixed, composition 1/2 watt, 100 ohms, ±10%	RC20GF101K
R4, R9, R19, R20	RESISTOR, fixed, composition 1 watt, 33,000 ohms, ±10%	RC30GF333K
R10, R33, R118, R208, R280, R521	RESISTOR, fixed, composition 1 watt, 1000 ohms, ±10%	RC30GF102K
R11	RESISTOR, fixed, composition 1 watt, 10 ohms, ±10%	RC30GF100K
R12,R16,R428,R429,R430	RESISTOR, fixed, composition 1/2 watt, 470,000 ohms, ±10%	RC20GF474K
R13, R17, R18, R21	RESISTOR, fixed, composition 1/2 watt, 12 ohms, ±10%	RC20GF120K
R14	RESISTOR, fixed, composition 1/2 watt, 47 ohms, ±10%	RC20GF470K
R22, R29, R271, R340, R347	RESISTOR, fixed, composition 1 watt, 4700 ohms ±10%	RC30GF472K
R24, R225, R402, R702	RESISTOR, fixed, composition 1 watt, 68,000 ohms, ±10%	RC30GF683K
R25, R213, R250, R436 R16 (2 used)	RESISTOR, fixed, composition 1 watt, 1500 ohms, ±10%	RC30GF152K
R26, R255, R354, R372, R380, R384 R393, R399, R401, R426	RESISTOR, fixed, composition 1 watt, 10,000 ohms, ±10%	RC30GF103K

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	PART NO.
R27, R31, R34, R202, R206, R210, R419, R486, R488	RESISTOR, fixed, composition 1/2 watt, 1 meg, ±10%	RC20GF105K
R28, R32	RESISTOR, fixed, composition 1/2 watt, 120 ohms, ±10%	RC20GF121K
R30	RESISTOR, fixed, composition 1/2 watt, 1200 ohms, ±10%	RC20GF122K
R35, R41	RESISTOR, fixed, composition 2 watt, 100,000 ohms, ±10%	RC42BF104K
R36, R415	RESISTOR, fixed, composition 1 watt, 470 ohms, ±10%	RC30GF471K
R37, R522	RESISTOR, fixed, composition 1 watt, 39,000 ohms, ±10%	RC30GF393K
R38, R487	RESISTOR, fixed, composition 1 watt, 150,000 ohms, ±10%	RC30GF154K
R40	RESISTOR, fixed, composition 1/2 watt, 56 ohms, ±10%	RC20GF560K
R42, R273, R390, R416 R485	RESISTOR, fixed, composition 1 watt, 22,000 ohms ±10%	RC30GF223K
R43	RESISTOR, fixed, composition 1/2 watt, 3300 ohms, ±10%	RC20GF332K
R44, R287, R489, R1118	RESISTOR, fixed, composition 1/2 watt, 10,000 ohms, ±10%	RC20GF103K
R101, R117	RESISTOR, fixed, composition 1/2 watt, 68,000 ohms, ±10%	RC20GF683K
R102, R112	RESISTOR, fixed, composition 1/2 watt, 130,000 ohms, ±5%	RC20GF134J
R103, R113	RESISTOR, fixed, composition 1/2 watt, 270,000 ohms, ±10%	RC20GF274K
R104, R114	RESISTOR, fixed, composition 1/2 watt, 560,000 ohms, ±10%	RC20GF564K
R105, R106, R115, R116	RESISTOR, fixed, composition 1/2 watt, 33,000 ohms, ±10%	RC20GF333K
R109, R121	RESISTOR, fixed, composition 1/2 watt, 150,000 ohms, ±10%	RC20GF154K
R111, R220	RESISTOR, fixed, composition 1 watt, 2700 ohms, ±10%	RC30GF272K
R201, R411, R413	RESISTOR, fixed, composition 1 watt, 560 ohms, ±10%	RC30GF561K
R203, R207	RESISTOR, fixed, composition 1/2 watt, 22 meg, ±10%	RC20GF226K
R204, R494, R500, R504, R507, R508, R512, R515, R607 (uses 2), R1107	RESISTOR, fixed, composition 1/2 watt, 1000 ohms, ±10%	RC20GF102K
R209	RESISTOR, fixed, composition 1/2 watt, 2200 ohms, ±10%	RC20GF222K
R212, R221, R272, R437, R439, R445, R448, R454, R457, R463, R466, R472, R476, R505, R514	RESISTOR, fixed, composition 1 watt, 100,000 ohms, ±10%	RC20GF224K
R214, R320	RESISTOR, fixed, composition 1 watt, 5100 ohms, ±5%	RC30GF512J
R215, R319, R704	RESISTOR, fixed, composition 1 watt, 6200 ohms, ±5%	RC30GF622J
R216, R321	RESISTOR, fixed, composition 1 watt, 270 ohms, ±5%	RC30GF271J
R217	RESISTOR, fixed, composition 1 watt, 390 ohms, ±5%	RC30GF391J
R218	RESISTOR, fixed, composition 1 watt, 1800 ohms, ±10%	RC32BF182K
R219, R322	RESISTOR, fixed, composition 1 watt, 560 ohms, ±5%	RC30GF561J
R222	RESISTOR, fixed, composition 1 watt, 680,000 ohms, ±10%	RC30GF684K
R223, R228, R363, R375, R397, R533	RESISTOR, fixed, composition 1 watt, 56,000 ohms, ±10%	RC30GF563K
R226, R227, R310, R317 R329, R608 (2 used), R609 (2 used), R1108, R1109 R341, R348	RESISTOR, fixed, composition 2 watts, 8200 ohms, ±10%	RC42GF822K

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	PART NO.
R229, R421, R710	RESISTOR, fixed, composition 1 watt, 560,000 ohms, ±10%	RC30GF564K
R230, R277, R359	RESISTOR, fixed, composition 1 watt, 390,000 ohms, ±10%	RC30GF394K
R231, R425, R603(2 used) R1103	RESISTOR, fixed, composition 1 watt, 180,000 ohms, ±10%	RC30GF184K
R232, R240, R427	RESISTOR, fixed, composition 1 watt, 470,000 ohms ±10%	RC30GF474K
R233, R497	RESISTOR, fixed, composition 1 watt, 1.5 meg, ±10%	RC30GF155K
R234	RESISTOR, fixed, composition 1 watt, 2.7 meg, ±10%	RC30GF275K
R235	RESISTOR, fixed, composition 1 watt, 4.7 meg, ±10%	RC30GF475K
R236, R244, R278, R414	RESISTOR, fixed, composition 1 watt, 100 ohms, ±10%	RC30GF101K
R238, R431, R496, R605 2 used, R1105	RESISTOR, fixed, composition 1 watt, 47,000 ohms, ±10%	RC30GF473K
R239	RESISTOR, fixed, composition 1 watt, 120 ohms, ±10%	RC30GF121K
R241, R275, R420, R433	RESISTOR, fixed, composition 1 watt, 1 meg, ±10%	RC30GF105K
R242, R1119	RESISTOR, fixed, composition 1/2 watt, 5600 ohms, ±10%	RC20GF562K
R243, R260	RESISTOR, fixed, composition 1 watt, 330 ohms, ±10%	RC30GF331K
R246, R286	RESISTOR, fixed, composition 1/2 watt, 1500 ohms, ±10%	RC20GF152K
R247, R318, R324, R377, R707, R708	RESISTOR, fixed, composition 1 watt, 15,000 ohms, ±10%	RC30GF153K
R249, R254, R267	RESISTOR, fixed, composition 2 watts, 6800 ohms, ±10%	RC42GF682K
R253, R482, R483	RESISTOR, fixed, composition 1 watt, 270 ohms, ±10%	RC30GF271K
R258, R259	RESISTOR, fixed, composition 2 watts, 6800 ohms, ±5%	RC42GF682J
R261	RESISTOR, fixed, composition 1 watt, 240 ohms, ±5%	RC30GF241J
R264, R266	RESISTOR, fixed, composition 2 watts, 8200 ohms, ±5%	RC42GF822J
R265, R1116	RESISTOR, fixed, composition 1 watt, 2200 ohms,, ±10%	RC30GF222K
R268, R281, R499	RESISTOR, fixed, composition 1 watt, 220,000 ohms, ±10%	RC30GF224K
R274	RESISTOR, fixed, composition 1 watt, 820 ohms, ±10%	RC30GF821K
R276, R290, R484	RESISTOR, fixed, composition 1 watt, 1,200 ohms, ±10%	RC30GF122K
R282, R441, R450, R459, R468, R477	RESISTOR, fixed, composition 1 watt, 6800 ohms, ±10%	RC30GF682K
R283, R407	RESISTOR, fixed, composition 1 watt, 56 ohms, ±5%	RC30GF560J
R285, R297, R298, R342, R343	RESISTOR, fixed, composition 1 watt, 180 ohms, ±10%	RC30GF181K
R289	RESISTOR, fixed, composition 1/2 watt, 22,000 ohms, ±10%	RC20GF223K
R295, R296, R304, R305, R309, R316, R408, R409, R602, R611, R1102, R1111	RESISTOR, fixed, composition 2 watt, 4700 ohms, ±10%	RC42GF472K
R306, R440, R458, R474, R829	RESISTOR, fixed, composition 1 watt, 3300 ohms, ±10%	RC30GF332K
R311, R312, R331, R332, R400	RESISTOR, fixed, composition 1 watt, 220 ohms, ±10%	RC30GF221K
R315, R346, R371, R387 R404, R610	RESISTOR, fixed, composition 1 watt, 200,000 ohms, ±5%	RC30GF204J
R323, R337, R403, R422 R495, R394	RESISTOR, fixed, composition 1 watt, 3900 ohms, ±10%	RC30GF392K

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	PART NO.
R325, R360, R368	RESISTOR, fixed composition 1 watt, 5600 ohms, ±10%	RC30GF562K
R328	RESISTOR, fixed composition 2 watts, 10,000 ohms, ±10%	RC42GF103K
R336	RESISTOR, fixed, composition 2 watt, [illegible] ohms, ±10%	RC42GF183K
R365, R529, R530	RESISTOR, fixed composition 1 watt, 12,000 ohms, ±10%	RC30GF123K
R353, R358, R386, R395, R570, R574	RESISTOR, fixed, composition 2 watt, 5600 ohms, ±5%	RC42GF562J
R385, R566, R578, R589	RESISTOR, fixed composition 2 watt, 11000 ohms, ±5%	RC42GF113J
R562, R582	RESISTOR, fixed composition 2 watts, 5600 ohms, ±10%	RC42GF562K
R391, R442, R451, R460, R469, R478, R705	RESISTOR, fixed, composition 1 watt, 120,000 ohms, ±10%	RC30GF124K
R395, R423, R701, R706	RESISTOR, fixed composition 1 watt, 27,000 ohms, ±10%	RC30GF273K
R411, R412	RESISTOR, fixed, composition 1 watt, 82,000 ohms, ±10%	RC30GF823K
R432	RESISTOR, fixed, composition 1 watt, 390 ohms, ±10%	RC30GF391K
R435, R455, R464, R473	RESISTOR, fixed, composition 1/2 watt, 1.8 meg, ±10%	RC20GF185K
R438, R447, R465, R470, R478	RESISTOR, fixed, composition 2 watts, 22,000 ohms, ±10%	RC42GF223K
R443, R452, R461, R470, R480	RESISTOR, fixed, composition 1 watt, 2.7 meg, ±5%	RC30GF275J
R446	RESISTOR, fixed, composition 1 watt, 1.8 meg, ±10%	RC30GF185K
R447, R467	RESISTOR, fixed, composition 1 watt, 3,000 ohms, ±5%	RC30GF302J
R484	RESISTOR, fixed, composition 1/2 watt, 470 ohms, ±10%	RC20GF471K
R498	RESISTOR, fixed composition 1 watt, 3.9 meg, ±10%	RC30GF395K
R503, R506, R511, R513	RESISTOR, fixed, composition 2 watt, 100 ohms, ±10%	RC42GF101K
R520	RESISTOR, fixed composition 1 watt, 18,000 ohms, ±10%	RC30GF183K
R601, R1104	RESISTOR, fixed composition 1/2 watt, 82,000 ohms, ±10%	RC20GF823K
R612, R1112	RESISTOR, fixed, composition 1/2 watt, 47,000 ohms, ±10%	RC20GF473K
R613, R614, R1113, R1114	RESISTOR, fixed, composition 2 watts, 3,300 ohms, ±10%	RC42GF332K
R703	RESISTOR, fixed composition 1/2 watt 270 ohms ±10%	RC20BF271K
R709	RESISTOR, fixed, composition 1 watt 330,000 ohms, ±10%	RC30GF334K
R801, R804, R805, R808, R811, R812, R817, R818, R819, R822, R825, R826	RESISTOR, fixed composition 1 watt, 47,000 ohms, ±10%	RC32GF473K
R802, R806, R809, R813, R816, R820, R823, R827	RESISTOR, fixed, composition 1/2 watt, 240,000 ohms, ±5%	RC20GF244J
R803, R807, R810, R814, R815, R821, R824, R828	RESISTOR, fixed, composition 1/2 watt, 91,000 ohms, ±5%	RC20GF913J
R830	RESISTOR, fixed, composition 1/2 watt, 220,000 ohms, ±10%	RC20GF224K
R831	RESISTOR, fixed, composition 1/2 watt, 120,000 ohms, ±10%	RC20GF124K
R1106	RESISTOR, fixed, composition 1/2 watt, 390,000 ohms, ±10%	RC20GF394K
R1120	RESISTOR, fixed, composition 1/2 watt, 2.2 meg, ±10%	RC20GF225K
R251	RESISTOR, fixed, film 1 watt, 980,000 ohms, ±1%	RN25X9803F

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	PART NO.
R252	RESISTOR, fixed, film 1 watt, 490,000 ohms ±1% Dale Products, Inc.	RN25X4903F
R256, R262, R326, R330 R333, R383	RESISTOR, fixed, film 1 watt, 100,000 ohms, ±1% Dale Products, Inc.	RN25X1003F
R257, R263, R327, R334	RESISTOR, fixed, film 1 watt, 41,500 ohms ±1% Dale Products, Inc.	RN25X4152F
R269	RESISTOR, fixed, film 1 watt, 830,000 ohms, ±1% Dale Products, Inc.	RN25X8303F
R270	RESISTOR, fixed, film 1 watt, 305,000 ohms, ±1% Dale Products, Inc.	RN25X3053F
R291, R299	RESISTOR, fixed, film 1 watt, 24,500 ohms, ±1% Dale Products, Inc.	RN25X2452F
R292, R300	RESISTOR, fixed, film 1 watt, 14,000 ohms, ±1% Dale Products, Inc.	RN25X1442F
R293, R301	RESISTOR, fixed, film 1 watt, 15,800 ohms, ±1% Dale Products, Inc.	RN25X1582F
R294, R351, R352, R356, R357, R361, R364, R367, R369, R373, R376, R379, R381, R385, R388, R392	RESISTOR, fixed, film 1 watt, 62,000 ohms, ±1% Dale Products, Inc.	RN25X6202F
R307, R313, R344, R338	RESISTOR, fixed, film 1 watt, 79,000 ohms, ±1% Dale Products, Inc.	RN25X7902F
R308, R314, R339, R345	RESISTOR, fixed, film 1 watt, 33,000 ohms, ±1% Dale Products, Inc.	RN25X3302F
R502, R1110	RESISTOR, fixed, film 1 watt, 405,000 ohms, ±1% Dale Products, Inc.	RN25X4053F
R510	RESISTOR, fixed, film 1 watt, 144,000 ohms, ±1% Dale Products, Inc.	RN25X1443F
R517	RESISTOR, fixed, film 1 watt, 132,000 ohms, ±1% Dale Products, Inc.	RN25X1323F
R523	RESISTOR, fixed, film 1 watt, 181,000 ohms, ±1% Dale Products, Inc.	RN25X1813F
R525	RESISTOR, fixed, film 1 watt, 160,000 ohms, ±1% Dale Products, Inc.	RN25X1603F
R526, R528	RESISTOR, fixed, film 1 watt, 370,000 ohms, ±1% Dale Products, Inc.	RN25X3703F
R527	RESISTOR, fixed, film 1 watt, 316,000 ohms, ± 1% Dale Products, Inc.	RN25X3163F
R615, R617, R1115, R1117	RESISTOR, fixed, film 1/2 watt, 90,000 ohms, ±1% Dale Products, Inc.	RN15X9002F
R406	RESISTOR, fixed, wirewound 15 watts, 2000 ohms, ±5%	RW20G202
R490, R491, R492	RESISTOR, fixed, wirewound 22 watts, 800 ohms, ±5%	RW21G801
R495	RESISTOR, fixed, wirewound 22 watts, 5000 ohms, ±5%	RW21G502
R518, R519	RESISTOR, fixed, wirewound 22 watts, 5000 ohms, ±5%	RW21G401
R532	RESISTOR, fixed, wirewound 22 watts, 4500 ohms, ±5%	RW21G452

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	PART NO
R536	RESISTOR, fixed, wire-wound, 10 watts, 500 ohms, ±5%	RW31G501
R5	RESISTOR, variable, composition, 2 watts, 5000 ohms, ±10%	RV4ATRD502A
R15	RESISTOR, variable, composition, 2 watts, 500 ohms, ±10% Northeastern Engineering, Inc.	A-17874-7
R110, R122	RESISTOR, variable, composition, 2 watts, 250,000 ohms ±10%	RV4ATRD254A
R107, R119, R211, R224, R248, R441, R453, R462, R471, R480	RESISTOR, variable, composition, 2 watts, 50,000 ohms, ±10% Northeastern Engineering, Inc.	A-17874-4
R237, S203	RESISTOR, variable, composition, ¼ watt, 5 meg, ±10%, plus switch. Northeastern Engineering, Inc.	A-17817
R349, R398, R501, R509, R516, R524	RESISTOR, variable, composition, 2 watts, 20,000 ohms ±20% Northeastern Engineering, Inc.	A-17874-6
R350, R396	RESISTOR, variable, composition, 2 watts, 250,000 ohms, ±10% Northeastern Engineering, Inc.	A-17874-5
CR1 thru CR4 CR201 thru CR250 CR261 thru CR270 -spares CR1101 thru CR1103	SEMICONDUCTOR DEVICE, crystal diode	1N34A
XV1, XV2, XV3, XV4, XV5, XV7, XV210	SOCKET, electron tube, seven pin, miniature, Elco Corp.	BR316PHSPTD
XV6	SOCKET, electron tube, 7 pin, miniature	TS102P01
XV8	SOCKET, electron tube, 6 contacts, medium American Phenolic Corp.	77-MIP-6TM
XV201, XV204, XV208, XV219 thru XV223 XV236, XV255, XV256	SOCKET, electron tube, 9 contacts, miniature Cinch Mfg Co.	16112
XV202, XV203, XV205 thru XV207, XV209, XV211 thru XV218, XV234, XV 235, XV237 thru XV247, XV252 XV258 thru XV261, XV602 XV603, XV1102, XV1103	SOCKET, electron tube, 7 contacts, miniature Cinch Mfg Co.	14700
XV248	SOCKET, electron tube, 9 contacts, noval type Vector Electronic Co.	6-N-9TJG
XV249, XV250, XV251, XV253, XV254, XV257, XZ102, XZ103, XZ201 thru XZ209, XZ235	SOCKET, electron tube, 8 pin, octal	TS101P02
XV601, XV801 thru XV804 XV1101	SOCKET, electron tube, 9 contacts, miniature Cinch Mfg Co.	44F-16388
S204	SWITCH, push, momentary action, normally closed Northeastern Engineering, Inc.	A-17875
S1	SWITCH, rotary, 6 sections, 11 positions Northeastern Engineering, Inc.	17609
S2	SWITCH, rotary, 2 section, 3 positions Northeastern Engineering, Inc.	A-17604
S101, S103	SWITCH, rotary, 1 section, 6 positions Northeastern Engineering, Inc.	A-17605

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	PART NO.
S201	SWITCH, rotary 3 sections, 6 positions Northeastern Engineering, Inc.	A-17607
S206	SWITCH, rotary 2 sections, 5 positions Northeastern Engineering, Inc.	A-17606
S207	SWITCH, rotary 1 section, 5 positions Northeastern Engineering, Inc.	A-17608
S102, S105, S106, S202	SWITCH, toggle a single pole, double throw	ST12D
S104, S205, S208	SWITCH, toggle double pole, double throw	ST22N
	THERMOMETER, self-indicating, bi-metallic 60° C to 70° C Northeastern Engineering, Inc.	B17397
T204	TRANSFORMER, power step-up 480 V, center tapped, 500 ma Northeastern Engineering, Inc.	C-17400
T205	TRANSFORMER, power step-up & step-down 7 secondary windings:- 5 V, 6A; 460 V, 100 ma, C. T.; 5 V, 2 A; 6.3 V, 8 A; 6.3 V, 8 A; 6.3 V, 8 A; 6.3 V, 8 A. Northeastern Engineering, Inc.	C17401
T201	TRANSFORMER, pulse for 10 pps pulse rate, 1 microsecond width. Northeastern Engineering, Inc.	B17614
V1, V2, V5, V6, V7, V203 V207, V206, V210, V211, V217, V240	TUBE, electron pentode, sharp cut-off	6AH6
V3, V4, V202, V214, V241, V243, V244, V246, V247	TUBE, electron mixer	5725/6AS6W
V8	TUBE, electron indicator	6E5
V201, V256, V701	TUBE, electron twin triode	12AT7WA
V204, V208, V219 thru V222, V233, V236, V248 V601(2 used), V1101, V801 thru V804, V2101 thru V2104(5each, used), V3101, V3102, V3103, V3104	TUBE, electron medium mu twin triode Radio Corpn of America	5963
V205, V206	TUBE, electron thyrathron	5727/2d21
V212, V213, V215, V216 V218, V239	TUBE, electron sharp cut-off pentode General Electric Co.	6CB6
V234, V237, V238, V252 V260	TUBE, electron pentode, sharp cut-off	6AU6WA
V235, V242, V245	TUBE, electron diode	5726/6AL5W
V249, V250, V251	TUBE, electron rectifier.	5R4WGA
V253, V254	TUBE, electron twin triode	6080WA
V255	TUBE, electron triode	5687
V257	TUBE, electron rectifier	5Y3WGTA
V258, V259	TUBE, electron pentode	6005/6AQ5W
V261	TUBE, electron voltage regulator	OB2WA

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	PART NO.
V602, V603(2 used), V1102, V1103	TUBE, electron pentode, sharp cut-off	5654/6AK5W
V702	TUBE, electron twin triode -General Electric Co.	5844

ASSEMBLIES

REFERENCE SYMBOL	NAME OF PART AND DESCRIPTION	PART NO.
W201	CABLE, POWER Northeastern Engineering, Inc.	B17864
W202, W203	CABLE, R.F. Northeastern Engineering, Inc.	B17633
W204	CABLE, TEST Northeastern Engineering, Inc.	B17631
W205	CABLE, TEST Northeastern Engineering, Inc.	B17632
Z205 thru 209	COUNTER,DECADE, 40 Mc N.E. Engineering, Inc.	140-40
Z204	COUNTER, DECADE, 100 Mc N.E. Eng., Inc.	140-100
DL201	DELAY LINE Northeastern Engineering, Inc.	B17394
Z203	DISCRIMINATOR, Amplitude N.E. Eng., Inc.	C17823.
Z202	DIVIDER, Decade Northeastern Engineering, Inc.	D17822
Z235	OVEN, Crystal Northeastern Engineering, Inc.	B18463
Z201	TRIGGER,UNIT Northeastern Engineering, Inc.	C17825
Z102, Z103	TRIGGER UNIT Northeastern Engineering, Inc.	C17821